Northeast Fisheries Science Center Reference Document 12-20

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ABSTRACT

Hydrographic observations from eleven surveys spanning the Northeast U.S. Continental Shelf are combined into a descriptive overview of the broad-scale oceanographic conditions that were observed during 2011. Temperature and salinity observations are combined into six 2-month time periods in order to maximize both the spatial coverage of the data and its temporal resolution during the year. Maps of near-surface and near-bottom property distributions are presented for each bi-monthly period and time series of regional average properties are discussed for five geographic regions spanning the shelf: western Gulf of Maine (GOMW), eastern Gulf of Maine (GOME), Georges Bank (GBNK), and northern and southern Middle Atlantic Bight (MABN and MABS, respectively). Surface conditions along the entire Northeast U.S. Continental Shelf were generally warm and very fresh in 2011 relative to the reference period (1977-1987). Surface warming was largest in the spring in the southern Middle Atlantic Bight and in late summer elsewhere. Freshening was greatest in the surface waters near the coast in the western Gulf of Maine and southern MAB during periods of maximum spring discharge, suggesting some influence from local fresh water sources in these regions. A later period of enhanced freshening also appears to align with a second large peak in precipitation over the Northeastern United States. The surface freshening observed over Georges Bank and throughout the MAB penetrates to the bottom, while bottom waters in the Northeast Channel and deep basins of the GoM were saltier than normal reflective of slope water influences in these regions. A particularly large Gulf Stream meander was responsible for extraordinarily warm and salty conditions observed throughout the water column on the New England Shelf between October-December 2011.

INTRODUCTION

The Northeast Fisheries Science Center (NEFSC) conducts multiple surveys on the Northeast U.S. continental shelf each year in support of its ongoing mission to monitor the shelf ecosystem and assess how its components influence the distribution, abundance, and productivity of living marine resources. In support of this mission, the Oceanography Branch provides conductivity, temperature and depth (CTD) instruments to all NEFSC cruises for the measurement of water column profiles of temperature and salinity. In addition to providing oceanographic context to specific field programs, these data contribute to a growing database of historical measurements that are used to monitor seasonal and interannual variability in the water properties on the northeast continental shelf.

Broad-scale surveys, sampling the shelf from Cape Hatteras, North Carolina, into the Gulf of Maine, are conducted up to six times per year during shelf-wide spring and fall bottom trawl surveys and typically on four dedicated seasonal Ecosystem Monitoring (EcoMon) surveys. Profiles of conductivity, temperature and depth are collected at each station on these shelf-wide surveys. Observations are also collected on other more regionally focused NEFSC surveys, where station coverage varies depending on the objectives of the particular field program. During 2011, hydrographic data were collected on 11 individual NEFSC cruises, amounting to 1,840 profiles of temperature and salinity (Table 1). Here we present an annual summary of these observations, including surface and bottom distributions of temperature and salinity, as well as their anomalies relative to a consistent reference period. In addition, regional average values of temperature and salinity and their anomalies are computed for five different regions of the shelf during six bi-monthly periods. Finally, the volume and properties of the shelf water are examined for the Middle Atlantic Bight region.

DATA AND METHODS

The Oceanography Branch provides CTD instrumentation and support to all NEFSC programs requesting this service. Training in instrument maintenance and operation, including deployment, data acquisition, recovery and preliminary processing, is provided as needed prior to sailing. On NEFSC surveys, CTD instruments are typically deployed in one of two modes: (1) during a bongo net tow, the CTD instrument is mounted on the conducting wire above the bongo frame and data are collected as a double oblique profile with the ship steaming at approximately 2 knots, (2) during a non-net tow, the CTD is mounted vertically on the wire and the sensors are soaked for one minute at the surface prior to descent. The sensors are not soaked at the surface prior to descent during bongo tows, rendering the upper 30 meters or more of the downcast unreliable. For this reason, the up-cast profile data are routinely processed as the primary data for each station.

In 2011, hydrographic data were collected aboard the NOAA ships *Delaware II* and *HB Bigelow*, and the R/V *HR Sharp* using a combination of Seabird Electronics SBE-19 and SBE-19+ SEACAT profilers and SBE 9/11 CTD units (Table 1). All raw CTD profile data were processed ashore, using standard Seabird Electronics software to produce 1-decibar averaged profiles in ascii-formatted files. Water samples were collected twice daily at sea during vertical casts. Following each cruise, these samples were analyzed using a Guildline AutoSal laboratory salinometer to provide quality control for the CTD salinity data. A salinity offset was applied to instrument data if the mean difference between the reference Autosal readings and the CTD values exceeded +/- 0.01 (a threshold chosen based on the expected instrument accuracy.) Vertical density profiles were examined for inversions due to bad conductivity or temperature readings and/or sensor misalignment. Egregious cases were replaced with a flag value. The processed hydrographic data were loaded into ORACLE database tables and made publically available via anonymous ftp (ftp://ftp.nefsc.noaa.gov/pub/hydro). Cruise reports have been prepared for each survey listed in Table 1 and are available online (http://www.nefsc.noaa.gov/epd/ocean/MainPage). Readers are referred to the individual cruise reports for notes, property maps and aggregate data specific to a particular survey.

Here, we aim to provide a descriptive overview of the hydrographic sampling that was conducted in 2011 and to characterize the broad-scale oceanographic conditions that were observed. In order to maximize both the spatial coverage of the data and its temporal resolution, the processed 2011 CTD data have been sorted into six 2-month time bins. Maps of near-surface and near-bottom temperature and salinity have been produced from profile data falling within each 2-month period. Surface fields include the shallowest observed temperature/salinity at each station that is also in the upper 5 meters of the water column, while bottom maps include the deepest observation at each station that also falls within 10 meters of the reported water depth. In order to examine the spatial and temporal variability over broader areas of the shelf, average values have been computed from the data within five sub-regions spanning the Northeast U.S. Continental Shelf (Figure 1). Regional averages have been computed for the bi-monthly binned fields (Tables 2 and 3) and for individual cruises (Appendix Tables 1-5).

In order to characterize variability that is not related to seasonal forcing, anomalies have been calculated at each station relative to a standard reference period (1977-1987). During this period the NMFS Marine Resources Monitoring and Prediction (MARMAP) program repeatedly occupied stations spanning the entire Northeast U.S. Shelf so that an annual cycle could be constructed for water properties across all regions of the northeast shelf (Mountain et al., 2004; Mountain and Holzwarth, 1989). The anomalies presented here are defined as the difference between the observed 2011 value at individual stations and the expected value for each location and time of year based on this reference period. Similarly, regional anomalies are the area-weighted average of these anomalies within a given domain. The methods used and an explanation of uncertainties is presented in Holzwarth and Mountain (1990).

Finally, we calculate the temperature, salinity and volume of the shelf water in the Middle Atlantic Bight during 2011 and relate this to the conditions observed during the MARMAP reference period. Following Mountain (2003), the shelf water mass is defined as water within the upper 100 meters having salinity less than 34. For each survey in 2011, the area of a sub-region was apportioned among its stations by an inverse distance squared weighting. The shelf water volume at a given station is the thickness of the shelf water at the station multiplied by its apportioned area, and the total shelf water volume within the sub region is the sum of these products for all stations within the region. Similarly, the average temperature and salinity was calculated in the shelf water layer at each station and multiplied by the total shelf water volume for that station. The sum of these products over all stations within a given sub-region, divided by the total shelf water volume for the region, determines the volume-weighted average temperature and salinity. Anomalies in the property and volume of the shelf water mass are calculated relative to like variables derived from MARMAP hydrographic data, as described above. Hence, here regional anomalies are computed as the mathematical difference between regional averages, *not* an average of the anomalies computed for a given sub-region.

RESULTS

Table 1 provides a listing of the NEFSC cruises that collected hydrographic data in 2011. In total, 1840 profiles of temperature and salinity were collected, processed and archived during the year. Combining the hydrographic data from multiple cruises into bi-monthly bins improves the spatial coverage compared with that of individual surveys, enabling us to examine the spatial and temporal patterns in hydrography over the region. Nonetheless, there are still significant gaps in several of the bi-monthly distribution maps shown in Figure 2. For instance, the lack of sampling over the Northeast Shelf during July-August was a consequence of the cancellation of the August Ecosystem Monitoring (EcoMon) cruise. There were also significant gaps in station coverage in portions of the Gulf of Maine during the March-April and September-October periods. These gaps result from a misalignment between the bi-monthly periods and the longer bottom trawl surveys that work from south to north along the shelf. These periods encompass all but the final portion of the spring and fall ground fish surveys, when sampling was focused in the Gulf of Maine. Large gaps in station coverage preclude the calculation of a representative regional average surface/bottom temperature and salinity value during July/August, particularly in the Gulf of Maine (Tables 2 and 3, Figures 3 and 4). While station coverage is substantially better during all other periods, not all of the average properties reported are true area-weighted averages representative of the entire region. Those cases are flagged in Tables 2 and 3 and the reader should keep this in mind when interpreting results.

Overall, surface conditions along the entire Northeast U.S. Continental Shelf were warm and very fresh in 2011 relative to the reference period (Figures 3 and 4). The warmest surface anomalies were observed in the MAB, peaking earlier in the south than the north (Figure 3). Surface temperatures in the MAB began the year colder than reference values, becoming warmer later in the year. This is consistent with long-term trends in the region, indicating that the seasonal temperature range has been increasing throughout the recent decade (Friedland and Hare, 2007). Surface waters were freshest in the southern MAB, measuring over 1.0 unit fresher than the MARMAP reference period during May-October (Figure 4). Bottom waters were warmer than normal in the Gulf of Maine with peak warming in the western region (Figure 3). By contrast, bottom waters on Georges Bank and in the northern MAB were near the reference temperature at the beginning of the year, becoming warmer through spring and fall, while temperatures remained near reference values in the southern MAB. Freshening was observed near the bottom on Georges Bank and in the Middle Atlantic Bight while bottom waters in the Gulf of Maine were not significantly different than the reference salinity at any point in the year. Compared with the reference period, the shelf water volume in the MAB was high in 2011 relative to the MARMAP period (salinity less than 34), with largest volume anomalies observed in the southern MAB. This suggests that the shelf/slope front, typically identified by the 34 isohaline, was consistently located seaward of its position during the reference period (Figure 5). On average, the shelf water was up to 0.7 units fresher over the entire MAB and the temperature was consistently warmer than the reference temperature in the north.

Details related to the temporal trends in Figures 3 and 4 are explored in surface and bottom property distribution maps (Figures 6-11). Maps of surface temperature reveal the seasonal cycle of warming and cooling over the region, with warmest temperatures observed at the surface during late summer (Figures 6-11a). Even though regional averages indicate warming over most of the region relative to the MARMAP reference period, the details of this warming varies from region to region. Cooler anomalies dominate most of the shelf during

January/February, although warm anomalies are observed at the surface over the Northeast Channel and Georges Bank (Figure 6b). At the onset of seasonal warming (May/June), warm anomalies dominate all regions of the shelf (Figure 8b). It should be noted that the tongue of cooler surface water extending southwestward across the MAB from Cape Cod to the shelf edge near Maryland is an artifact of combining two surveys that occupied adjacent stations at different times: the colder stations were occupied in mid-May while the surrounding warmer stations were occupied in early June (Figure 8a). This cold feature disappears when contouring temperature distributions observed during a single shelf-wide survey (Figure 8c; Table 1). The May/June anomaly map shows warming over the entire region (Figure 8b), demonstrating that our method is successful at removing temporal variations associated with the seasonal cycle.

Seasonal cooling typically begins in September/October, with colder isotherms gradually pushing southward along the shelf. Cold anomalies observed on the shelf between 38-40N during September/October are suggestive of interannual variations in this progressive cooling of surface waters (Figure 10b). Also of note, surface temperatures were up to 8C warmer (and 2 units saltier) during this period at the edge of the shelf south of Cape Cod (Figure 10b). Similarly, in November/December 2011 the sea surface was anomalously warm over Nantucket Shoals and along the shelf edge south of Cape Cod, establishing a sharp temperature gradient at this location (Figure 11). These warm anomalies were particularly strong near the bottom (Figure 11b) and collocated with the warm/salty anomalies observed in September/October (Figure 10b). The anomalous features were forced by an extraordinarily large meander in the Gulf Stream that brought extremely warm/salty water into contact with the shelf and slope in this region during two periods, early-November and December 2011 (Gawarkiewicz et al., 2012).

Maps of surface salinity show the seasonal influence of freshwater discharge in the nearshore regions, with the freshest waters appearing very near the coast in the eastern Gulf of Maine and MAB in March/April, followed by more wide-spread freshening over these regions in May/June (Figures 7a and 8a). While overall surface waters were fresher than normal in 2011, the largest anomalies were observed near the coast in the vicinity of major freshwater sources (e.g., western Gulf of Maine, Hudson River, Delaware and Chesapeake Bays) during periods of maximum spring discharge (March/April and May/June; Figures 7b and 8b). Curiously, a second period of fresh anomalies was also observed near these freshwater sources in September/October (Figure 10b).

Maps of near bottom salinity and salinity anomaly suggest that freshening observed at the surface penetrates to the bottom on Georges Bank and throughout the MAB (Figures 4 and 6-11). However, the same is not true in the Gulf of Maine where slope water influences the lower layer properties. Near-bottom temperature and salinity anomalies in Northeast Channel and in the deep basins of the GoM suggest that the slope water was warmer and saltier throughout much of 2011 (Figures 6-11b).

Maps of near-bottom temperature show the seasonal formation of the cold pool in the Middle Atlantic Bight, with coldest temperatures observed during the May/June period (Figure 8a). It must be recognized that the shape and magnitude of the cold pool as seen in this composite map may be influenced by the same temporal discontinuity between adjacent stations that led to artifacts in the surface fields. In fact, the position of the cold pool in Figure 8a lies directly underneath this artificial surface feature. However, it is reassuring that the cold pool feature is also evident in bottom maps constructed from the single June EcoMon Survey (Figure 8c; Table 1). The accompanying maps of near-bottom temperature anomaly suggest that temperatures at the core of the temperature minimum were slightly warmer than normal, while temperatures in the southern tail of the feature were slightly colder than normal (Figures 8b and 8d). By September/October the cold pool had begun to weaken and warm (Figure 10a). Cold anomalies near the core are indicative of interannual variations in the erosion of this feature (Figure 10b).

The erosion of the cold pool in late summer is preceded by warming of bottom waters near the coast in September/October (compare Figures 8a and 10a). This is consistent with historical observations in this region, which indicate that by late summer the effects of seasonal heating extend all the way to the ocean bottom in the near-shore regions (Castelao et al., 2010). The anomaly fields shown in Figure 10b suggest that near-shore bottom waters north of 38N were 2-3 degrees warmer in 2011 than the reference period.

Based on the climate summaries compiled by the Northeast Regional Climate Center (http://www.nrcc.cornell.edu), monthly mean air temperatures over the Northeastern U.S. were warmer than the long term mean throughout most of 2011 (referenced to 1971-2000). On average, annual mean temperatures were almost 1.5 degrees warmer than normal. The annual cycle of heating and cooling in 2011 was aligned with the long-term annual cycle but warming was enhanced during the peak in seasonal heating (3 degrees above normal) and again in late fall (over 5 degrees warmer, Figure 12). By comparison, the largest regional sea surface temperature anomalies were observed in September/October in the north and May/June in the south.

According to Northeast Regional Climate Center records, the annual mean precipitation over the Northeastern U.S. was above normal for 7 months out of 2011 (referenced to 1971-2000). Most notably, precipitation was elevated from March-May (almost 3” above normal) and again in August-October (over 4” above normal). The two periods of enhanced precipitation may account for the anomalously fresh surface conditions observed near the Hudson River, Delaware and Chesapeake Bays and along the coast in the western Gulf of Maine during the May/June and September/October time periods (Figures 8 and10). However, a more thorough analysis would be needed to discriminate between local freshening due to precipitation and river run-off and freshening due to advection from remote sources.

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Table 1. Listing of 2011 NOAA Northeast Fisheries Science Center cruises supported by the Oceanography Branch

Cruise	Program	Dates	Region(s)[1]	Gear	Casts
DEL1101	LMRCSC/COOP	12 - 19 Jan	South MAB	SBE-19/ 19+	33
DEL1102	EcoMon	1 - 18 Feb	Full Shelf	SBE-19+	192
HB1102	Spring Bottom Trawl	3 Mar - 12 May	Full Shelf	SBE-19	353
S11101	Scallop Survey	12 May - 18 Jun	GB, MAB	SBE-911+	86
DEL1105	EcoMon	2 - 21 Jun	Full Shelf	SBE-19+,/911+	269
HB1103	Cetacean Abundance	4 Jun - 31 Jul	MAB, GB	SBE-19/ 19+	106
HB1104	Habitat Mapping	5 - 11 Aug	HC	SBE-911+	29
DEL1108	Hydroacoustic	9 Sep - 13 Oct	GOM, GB	SBE-19+	193
HB1105	Fall Bottom Trawl	10 Sep - 14 Nov	Full Shelf	SBE-19+/19	353
DEL1109	EcoMon	31 Oct - 19 Nov	Full Shelf	SBE-19/19+/911+	139
DEL1110	EcoMon/Gear Test	1 - 8 Dec	West GOM, GB	SBE-19+	87

[1] Regional Abbreviation:
GOM=Gulf of Maine
GB=Georges Bank
MAB=Middle Atlantic Bight
HC=Hudson Canyon

Table 2. 2011 regional average surface and bottom temperature values computed from CTD data that were sorted into six 2-month time periods for the five regions of the Northeast U.S. continental shelf. Boundaries of Gulf of Maine East (GOME), Gulf of Maine West (GOMW), Georges Bank (GB), Middle Atlantic Bight North (MABN), and Middle Atlantic Bight South (MABS) are shown in Figure 1.

		SURFACE						BOTTOM					
Region	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
January-February													
GOME	45	23	4.50	-0.26	0.21	1.69	1	14	8.33	1.00	0.26	2.66	1
GOMW	45	52	5.00	0.04	0.20	0.77	0	41	7.48	1.75	0.19	1.08	0
GB	42	37	5.97	0.79	0.18	0.68	0	29	6.10	0.13	0.22	1.11	0
MABN	35	23	5.70	-0.47	0.27	0.92	0	17	6.03	-0.63	0.32	1.38	0
MABS	29	56	6.57	-0.73	0.19	1.25	0	38	6.60	-0.46	0.24	1.16	0
March-April													
GOME	115	27	5.83	0.38	0.19	2.03	1	26	8.03	1.06	0.19	1.84	1
GOMW	108	18	5.73	0.52	0.25	2.39	1	18	6.73	1.88	0.21	2.00	1
GB	99	55	5.57	0.37	0.14	1.03	0	42	6.03	0.77	0.17	0.92	0
MABN	82	55	5.19	0.61	0.17	0.83	0	47	5.09	-0.34	0.21	1.78	0
MABS	70	69	6.79	0.59	0.16	1.37	0	58	6.49	0.35	0.21	1.58	0
May-June													
GOME	162	27	9.94	0.73	0.19	1.15	0	21	8.22	0.79	0.23	1.04	0
GOMW	150	86	10.20	0.36	0.12	1.14	0	78	7.27	1.83	0.11	1.05	0
GB	163	89	11.52	0.94	0.12	1.34	0	79	8.51	0.31	0.13	1.00	0
MABN	158	84	14.93	1.74	0.15	1.26	0	75	8.73	0.96	0.17	1.47	0
MABS	150	84	18.44	2.48	0.15	1.76	0	80	9.29	-0.16	0.16	2.50	0
July-August													
GOME													
GOMW													
GB	199	4	16.83	-0.40	0.59	5.51	1	2	9.10	0.51	0.81	8.00	1
MABN	204	10	20.59	2.86	0.43	2.62	1	8	9.48	0.34	0.44	3.23	1
MABS	216	34	23.95	1.88	0.26	1.25	1	6	9.56	-0.71	0.56	3.31	1
September-October													
GOME	276	35	15.72	1.42	0.17	3.96	1	34	9.00	0.35	0.16	3.69	1
GOMW	271	161	16.51	1.48	0.08	1.75	1	161	8.03	1.68	0.07	1.56	1
GB	285	76	16.27	1.34	0.14	1.72	0	61	13.78	1.18	0.17	1.76	0
MABN	273	49	20.40	2.53	0.18	1.77	0	42	13.47	1.03	0.22	2.18	0
MABS	261	90	22.08	0.40	0.14	1.56	0	73	14.02	-0.02	0.18	2.29	0
November-December													
GOME	313	53	10.62	-0.22	0.20	1.84	1	45	8.89	0.25	0.22	2.14	1
GOMW	319	72	10.97	1.01	0.14	0.76	0	68	8.81	1.41	0.12	0.79	0
GB	325	59	12.48	0.89	0.15	1.57	0	52	12.67	1.59	0.16	1.66	0
MABN	316	54	14.11	0.61	0.24	1.63	0	48	14.66	1.87	0.25	1.52	0
MABS	311	39	15.70	0.17	0.22	1.47	0	37	15.09	0.49	0.25	1.11	0

"Region", the geographic region of the northeast continental shelf: "CD", the calendar mid-date of all the stations within a region for a time period: "#obs", the number of observations included in each average: "Temp", the areal average temperature: "Anomaly", the areal average temperature anomalies: "SDV1",the standard deviation associated with the average temperature anomaly: "SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived: "Flag", a value of "1" indicates that a true areal average could not be calculated due to poor station coverage. The areal averages listed were derived from a simple average of the observations within the region.

Table 3. 2011 regional average surface and bottom salinity values computed from CTD data that were sorted into six 2-month time periods for the five regions of the Northeast U.S. continental shelf shown in Figure 1. Boundaries of Gulf of Maine East (GOME), Gulf of Maine West (GOMW), Georges Bank (GB), Middle Atlantic Bight North (MABN), and Middle Atlantic Bight South (MABS) are shown in Figure 1.

		SURFACE						BOTTOM					
Region	CD	#obs	Salt	Anomaly	SDV1	SDV2	Flag	#obs	Salt	Anomaly	SDV1	SDV2	Flag
		January-February											
GOME	45	23	32.08	-0.70	0.15	0.89	1	14	34.43	0.16	0.13	1.06	1
GOMW	45	52	32.33	-0.66	0.13	0.42	0	41	33.55	0.00	0.11	0.43	0
GB	42	37	33.01	0.06	0.11	0.41	0	29	33.08	-0.10	0.13	0.35	0
MABN	35	23	32.82	-0.40	0.18	0.45	0	17	32.99	-0.60	0.19	0.46	0
MABS	29	56	33.00	-0.53	0.15	1.29	0	38	33.23	-0.28	0.15	0.49	0
		March-April											
GOME	115	27	32.15	-0.37	0.13	0.81	1	26	34.20	0.08	0.10	0.99	1
GOMW	108	18	32.12	-0.76	0.16	0.93	1	18	33.07	-0.10	0.12	1.08	1
GB	99	55	32.48	-0.52	0.08	0.39	0	42	32.84	-0.33	0.10	0.49	0
MABN	82	55	32.35	-0.54	0.11	0.61	0	47	32.64	-0.81	0.12	0.47	0
MABS	70	69	32.80	-0.46	0.12	1.04	0	58	33.12	-0.48	0.12	0.48	0
		May-June											
GOME	162	27	31.92	-0.45	0.14	0.33	0	21	34.01	0.06	0.12	0.45	0
GOMW	150	86	31.32	-0.82	0.08	0.76	0	78	33.28	0.00	0.07	0.53	0
GB	163	89	32.18	-0.69	0.07	0.36	0	79	32.55	-0.52	0.08	0.41	0
MABN	158	84	31.91	-0.54	0.10	0.79	0	75	32.61	-0.67	0.10	0.49	0
MABS	150	84	30.97	-1.20	0.12	1.56	0	80	32.80	-0.53	0.10	0.68	0
		July-August											
GOME													
GOMW													
GB	199	4	32.23	-0.89	0.34	1.82	1	2	32.44	-0.85	0.50	2.88	1
MABN	204	10	31.59	-1.32	0.25	0.89	1	8	32.32	-0.57	0.26	1.16	1
MABS	216	34	31.66	-1.58	0.17	0.58	1	6	32.24	-0.69	0.34	1.14	1
		September-October											
GOME	276	35	32.11	-0.41	0.11	1.33	1	34	34.35	0.01	0.09	1.12	1
GOMW	271	161	31.71	-0.48	0.05	0.59	1	161	33.76	0.13	0.04	0.48	1
GB	285	76	32.44	-0.31	0.08	0.61	0	61	32.61	-0.34	0.10	0.48	0
MABN	273	49	32.09	-0.58	0.12	1.32	0	42	32.90	-0.53	0.13	0.66	0
MABS	261	90	31.30	-1.01	0.11	1.48	0	73	32.10	-1.04	0.11	0.65	0
		November-December											
GOME	313	53	32.27	-0.53	0.14	0.86	1	45	34.18	-0.01	0.12	0.88	1
GOMW	319	72	32.24	-0.51	0.09	0.34	0	68	33.61	0.00	0.07	0.34	0
GB	325	59	32.33	-0.46	0.09	0.62	0	52	32.90	-0.18	0.10	0.56	0
MABN	316	54	32.46	-0.55	0.16	0.76	0	48	33.32	-0.34	0.15	0.62	0
MABS	311	39	32.32	-0.65	0.17	1.22	0	37	32.57	-0.82	0.15	0.61	0

"Region", the geographic region of the northeast continental shelf: "CD", the calendar mid-date of all the stations within a region for a time period: "#obs", the number of observations included in each average: "Salt", the areal average salinity: "Anomaly", the areal average salinity anomalies: "SDV1",the standard deviation associated with the average salinity anomaly: "SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived: "Flag", a value of "1" indicates that a true areal average could not be calculated due to poor station coverage. The areal averages listed were derived from a simple average of the observations within the region.

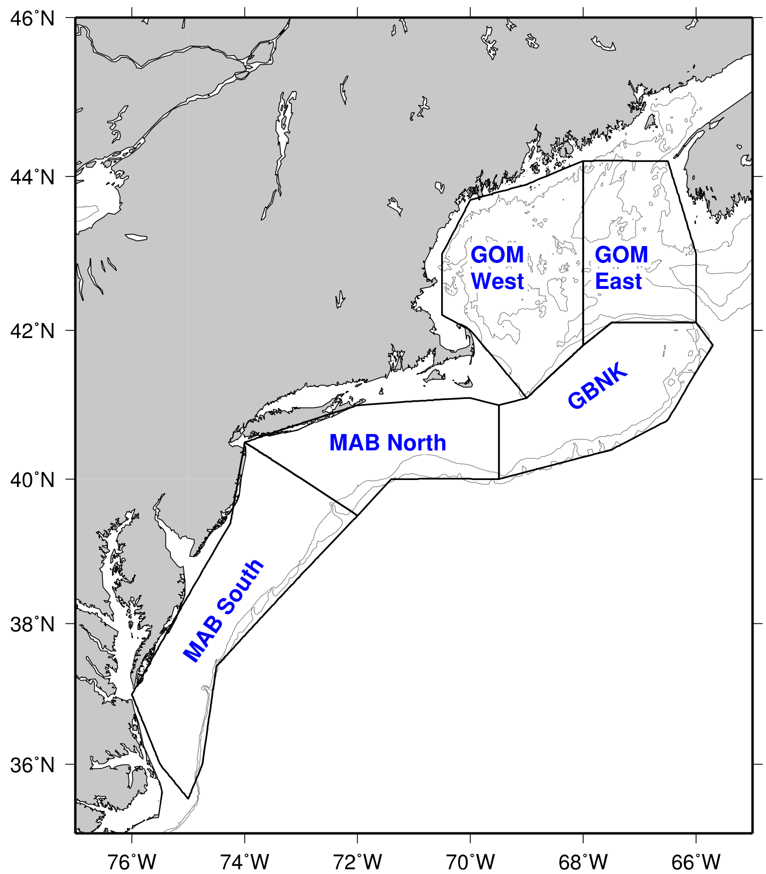

Figure 1. Region designations for the Northeast U.S. Continental Shelf: Gulf of Maine (GOM), Georges Bank (GB), Middle Atlantic Bight (MAB). The 100 m and 200 m isobaths are also shown.

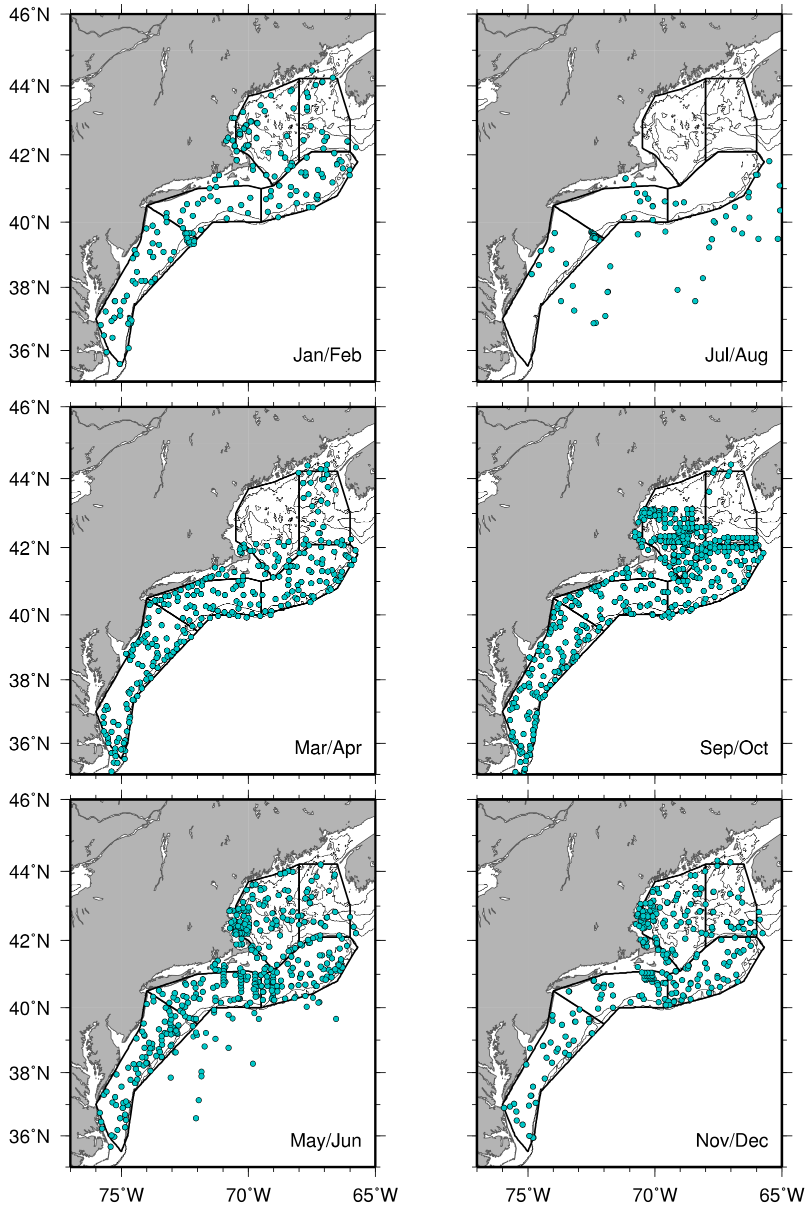

Figure 2. 2011 station distributions for each 2-month time period. The regional boundaries are also overlain. Contours indicate the 100 and 200-meter isobaths.

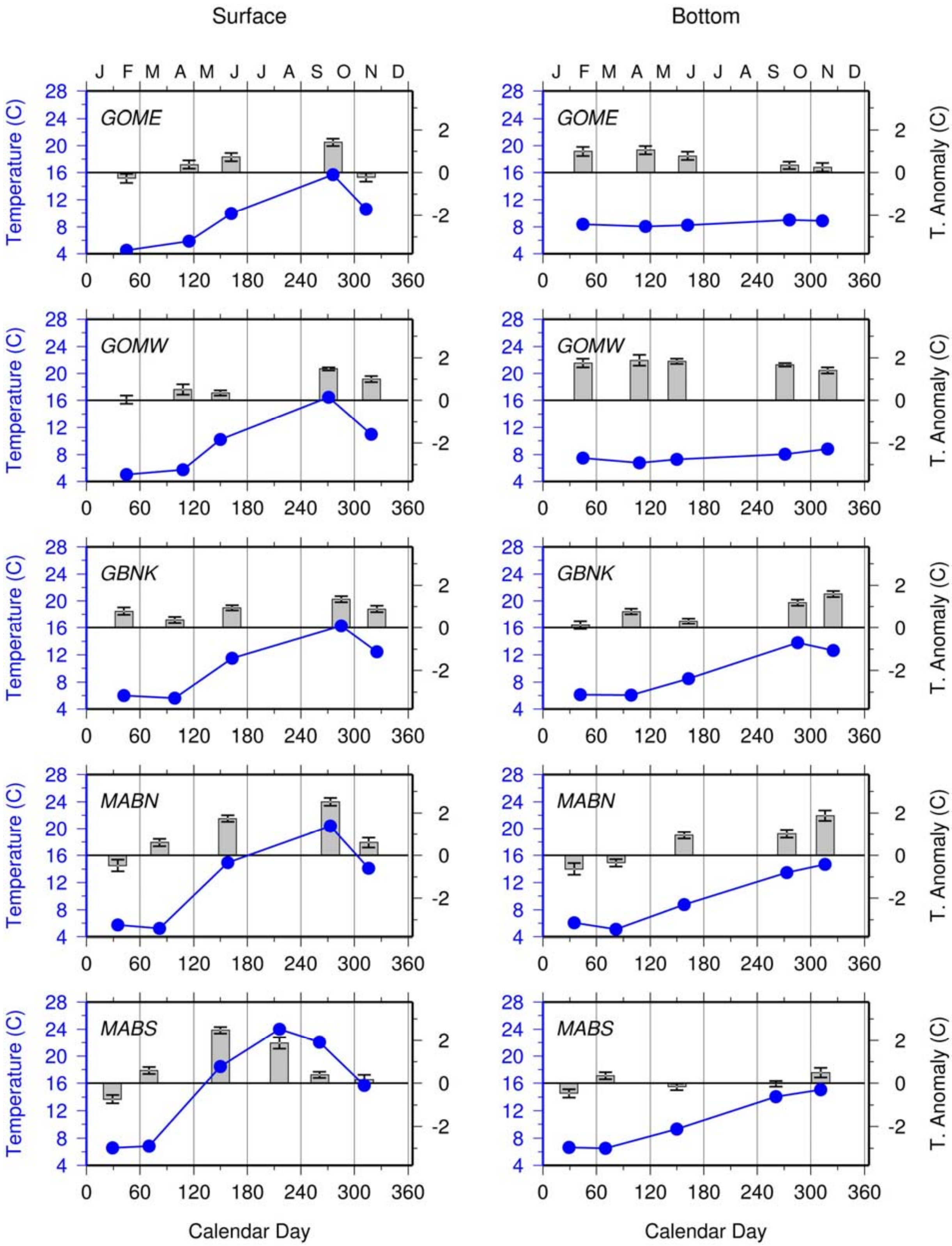

Figure 3. Time series of the 2011 regional surface (left) and bottom (right) temperatures (blue) and anomalies (bars) as a function of calendar day. Error bars are indicated for the anomaly estimates.

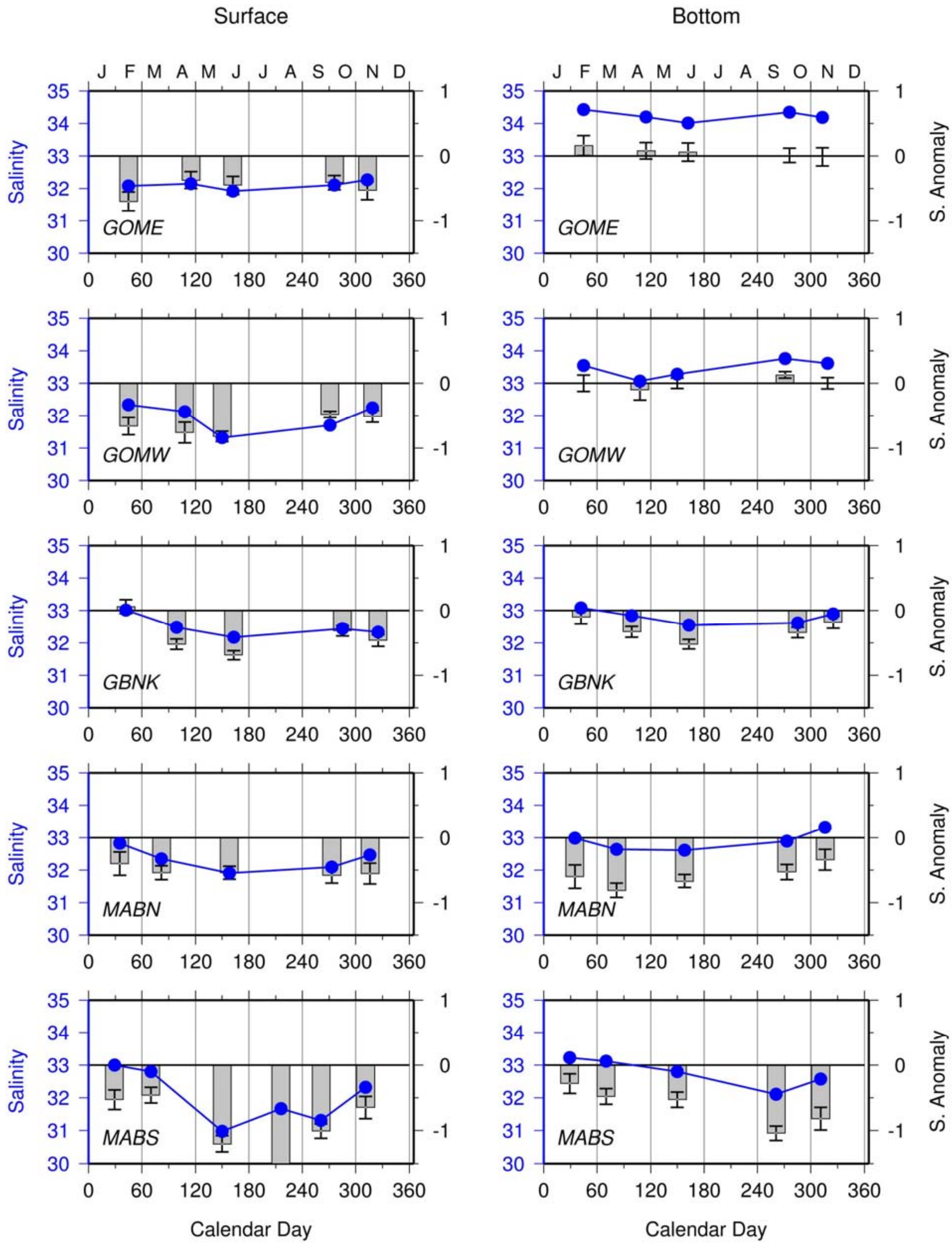

Figure 4. Time series of the 2011 regional surface (left) and bottom (right) salinities (blue) and anomalies (bars) as a function of calendar day. Error bars are indicated for the anomaly estimates.

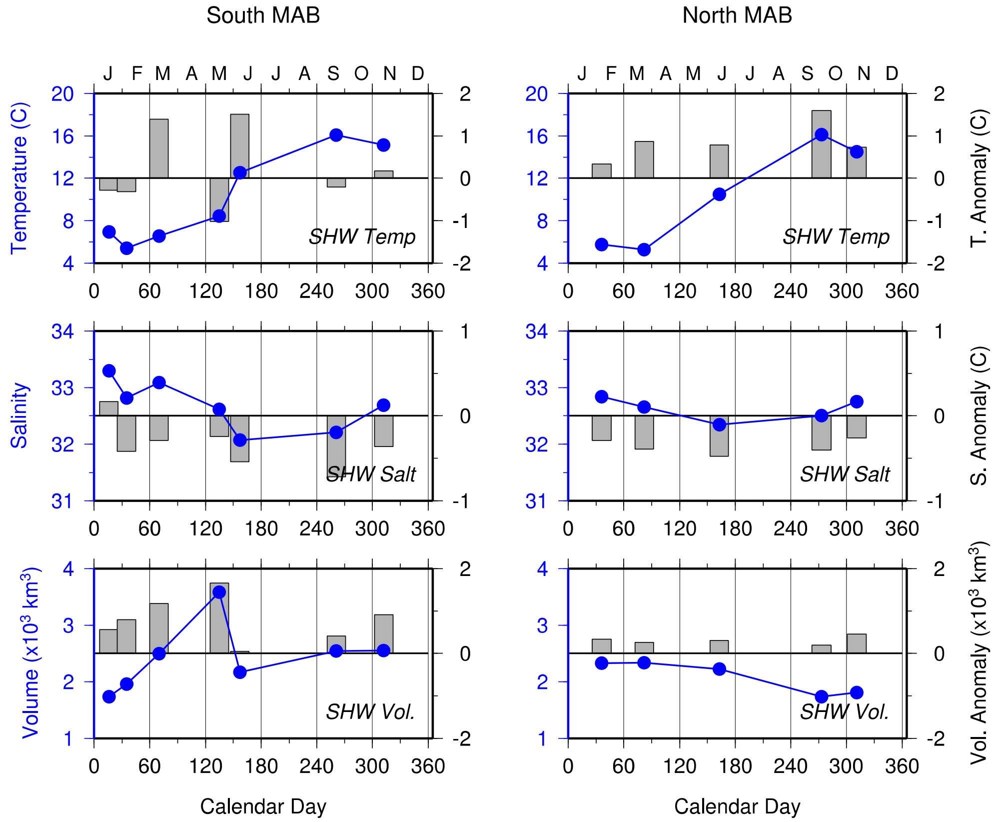

Figure 5. Time series of the 2011 regional shelf water temperature, salinity, and volume as a function of calendar day shown in blue for the southern (left) and northern (right) Middle Atlantic Bight. The vertical bars show the corresponding shelf water anomalies.

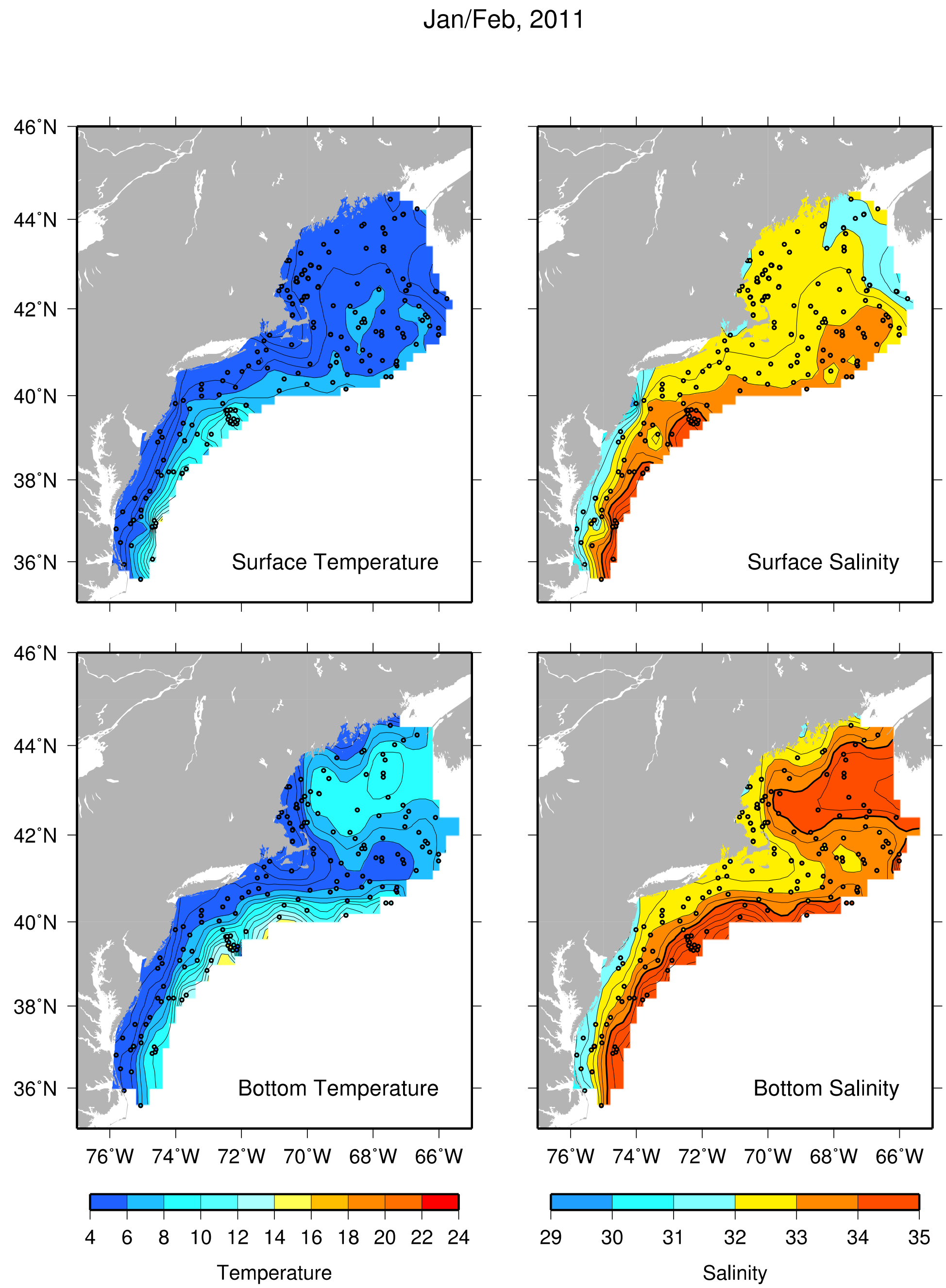

Figure 6a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during January-February 2011. Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

Jan/Feb, 2011

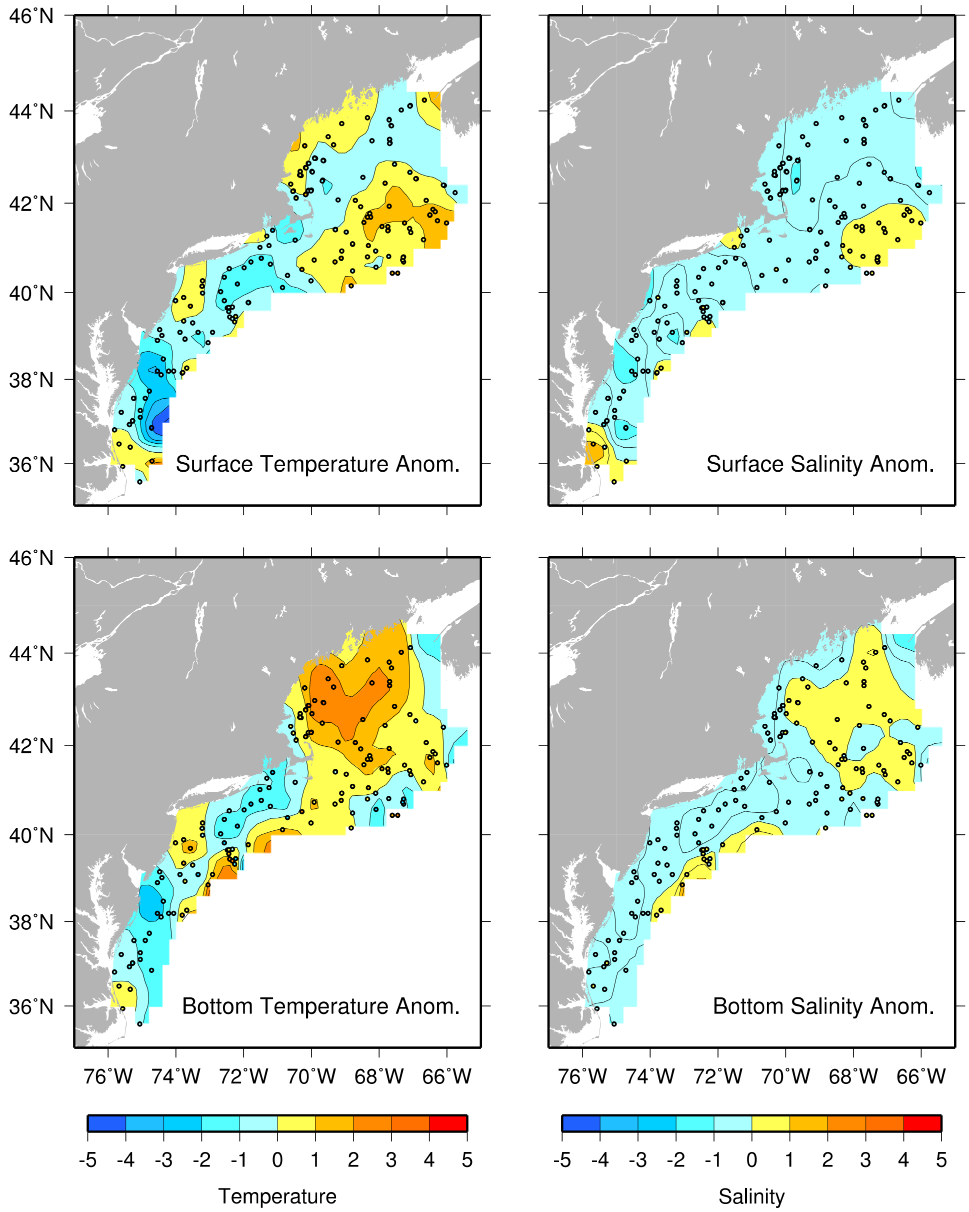

Figure 6b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during January-February 2011. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

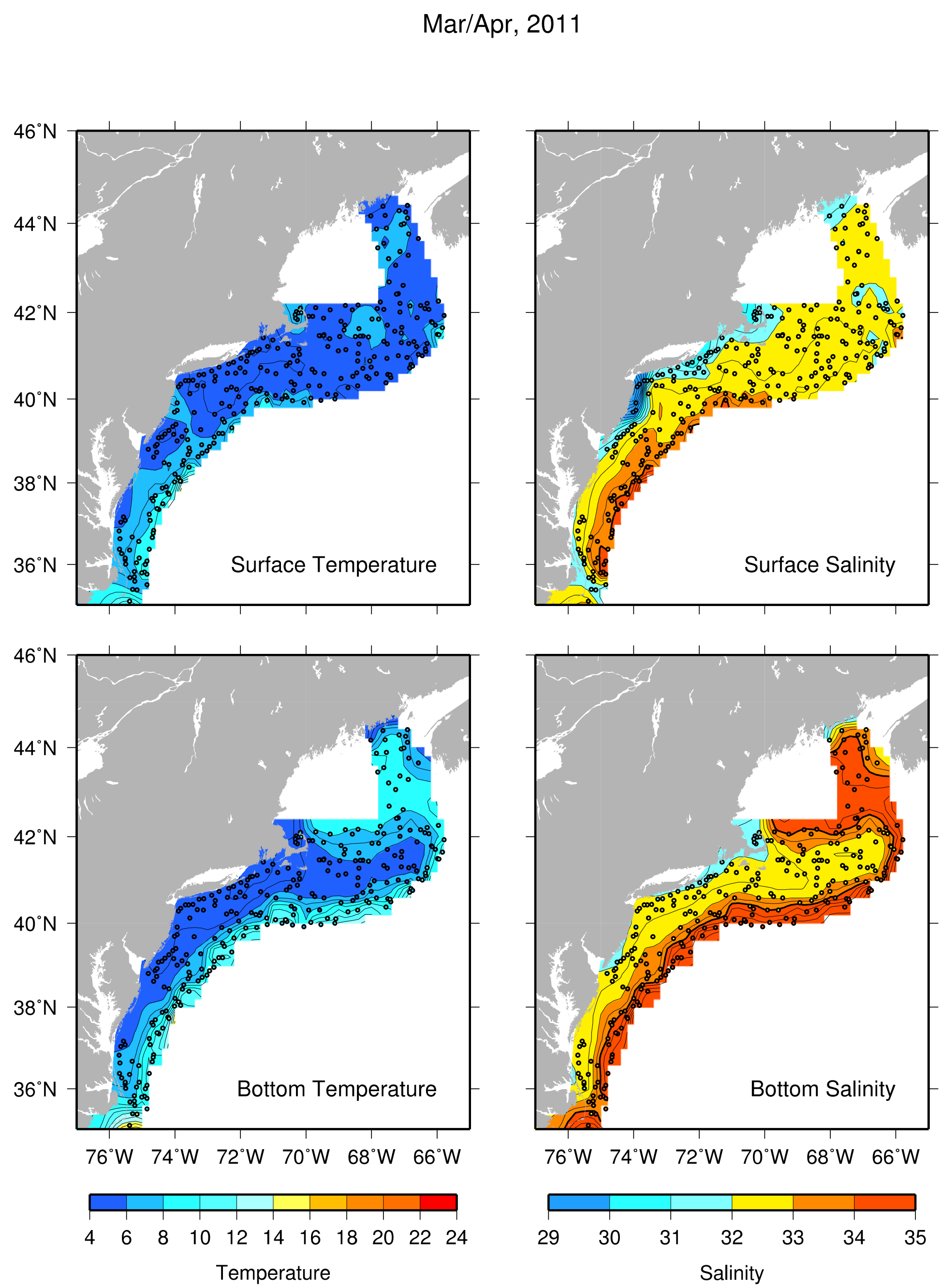

Figure 7a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during March-April 2011. Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

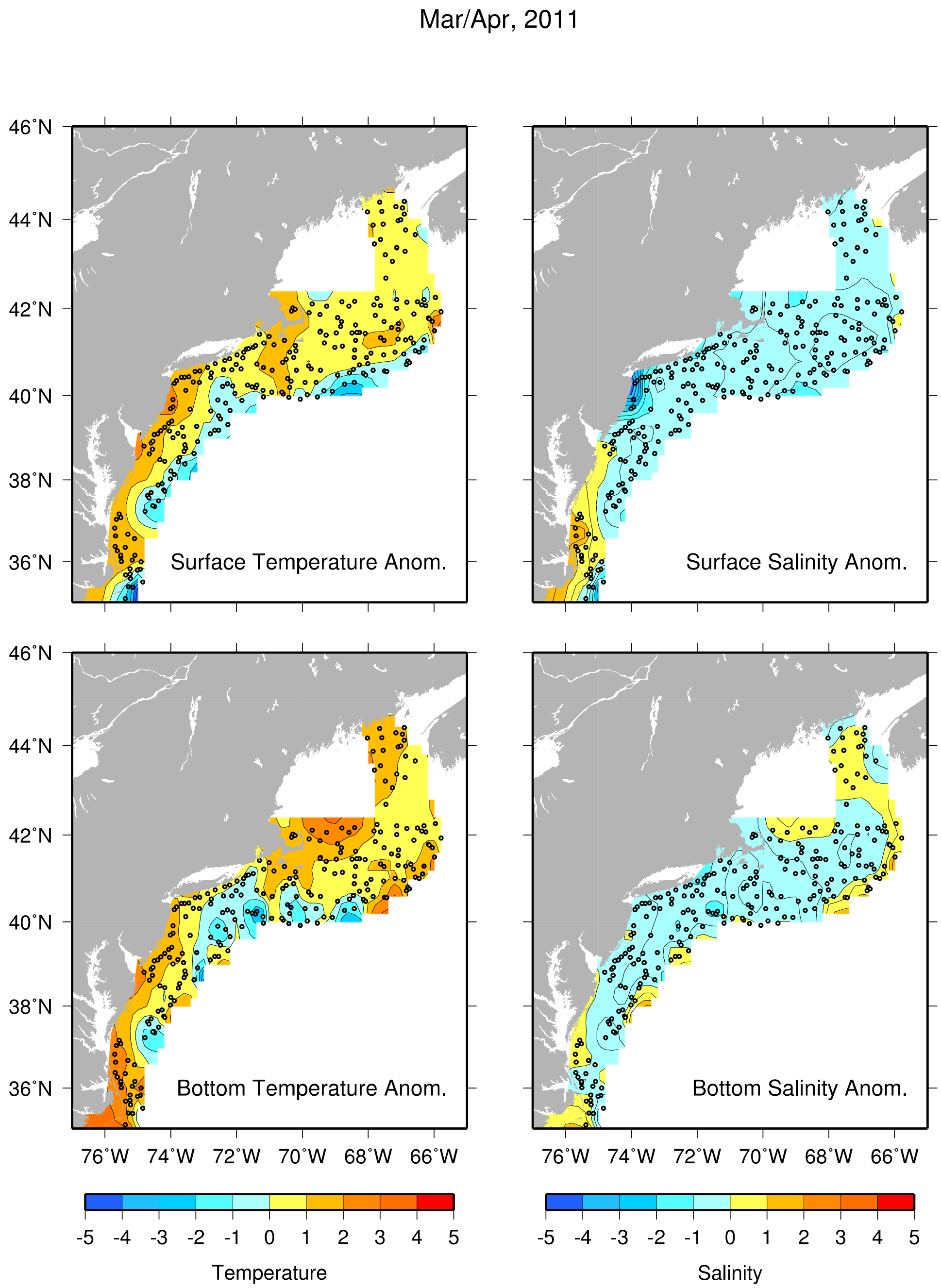

Figure 7b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during March-April 2011.

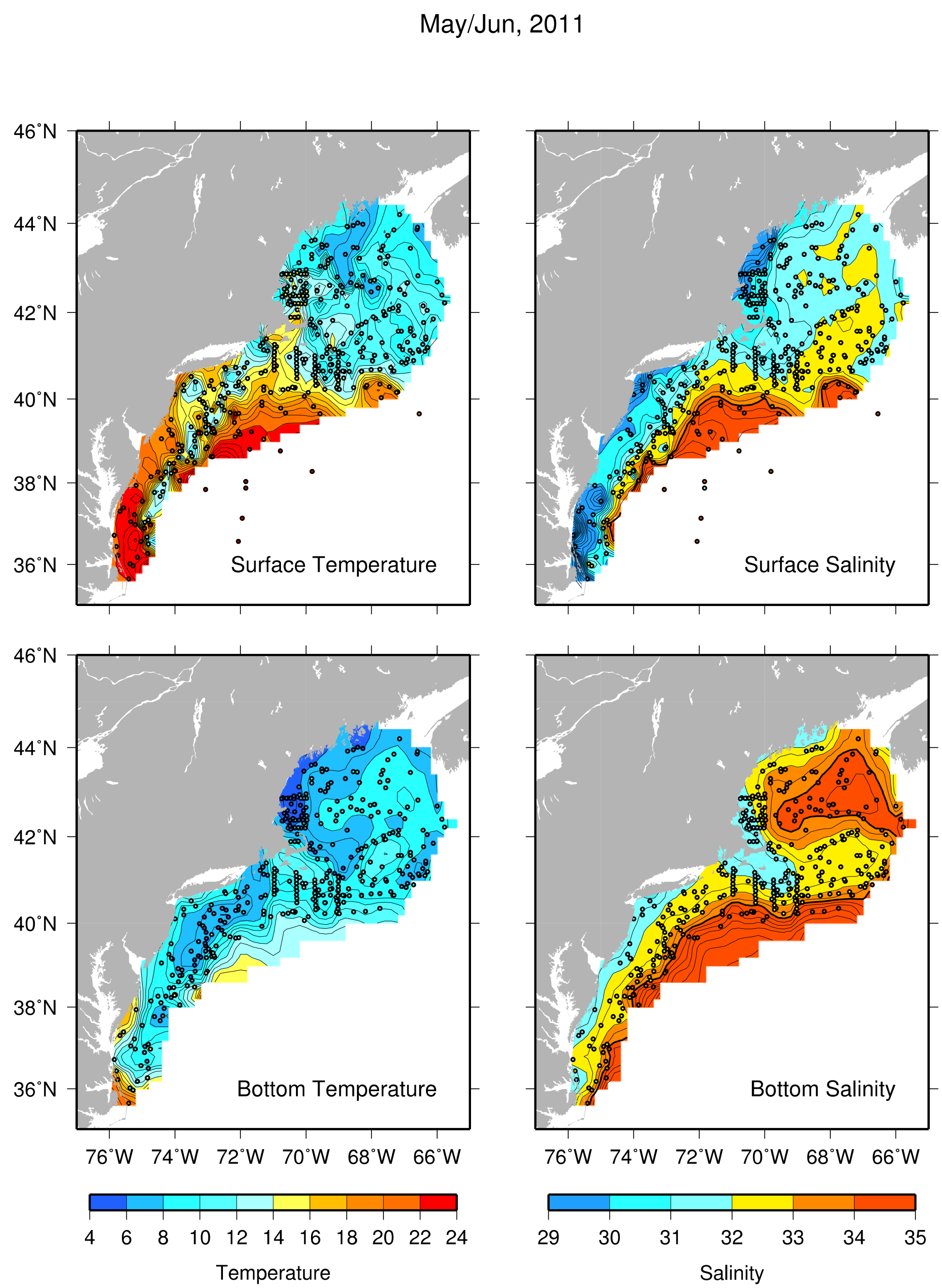

Figure 8a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during May-June 2011.Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

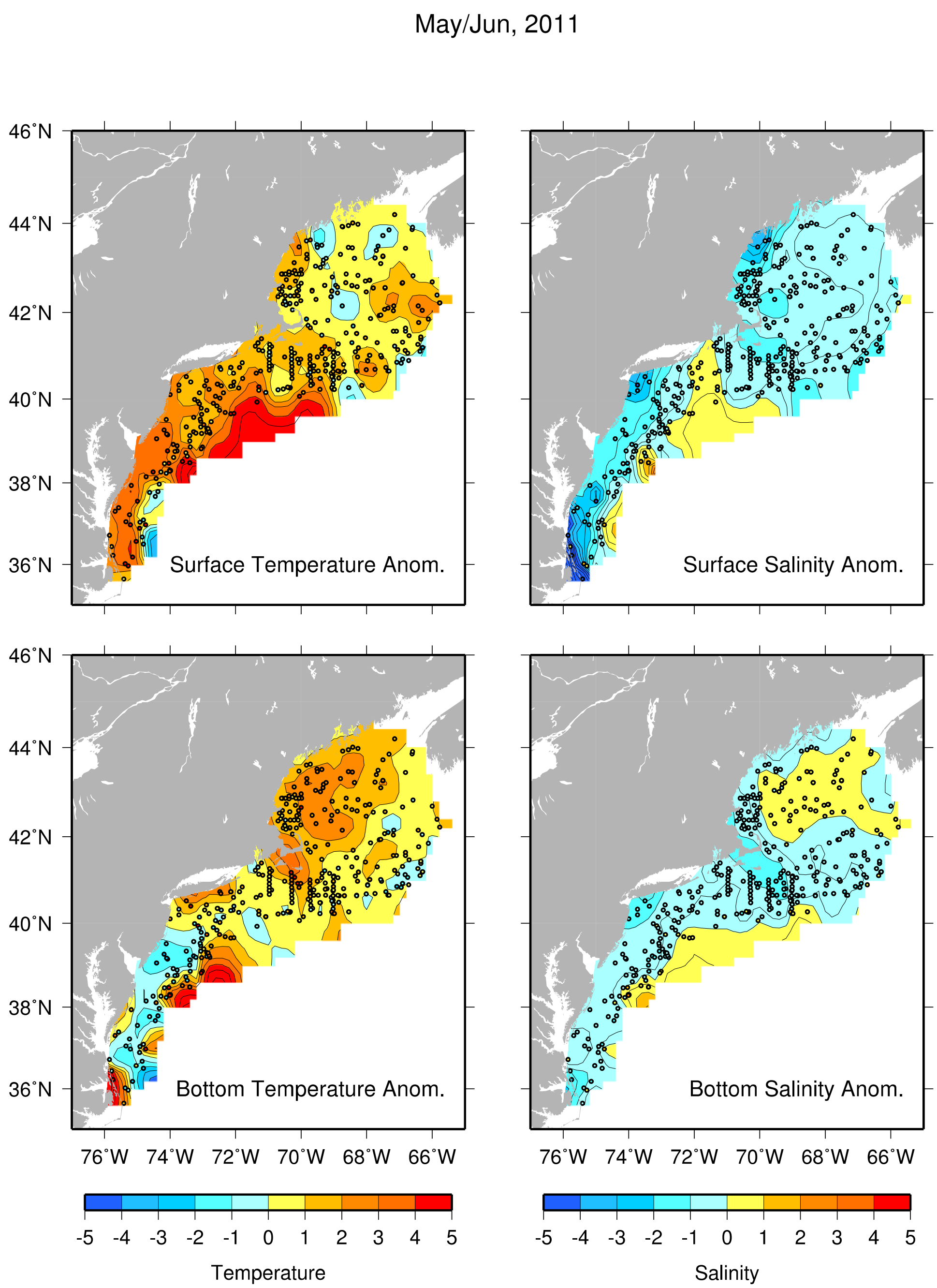

Figure 8b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during May-June 2011. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

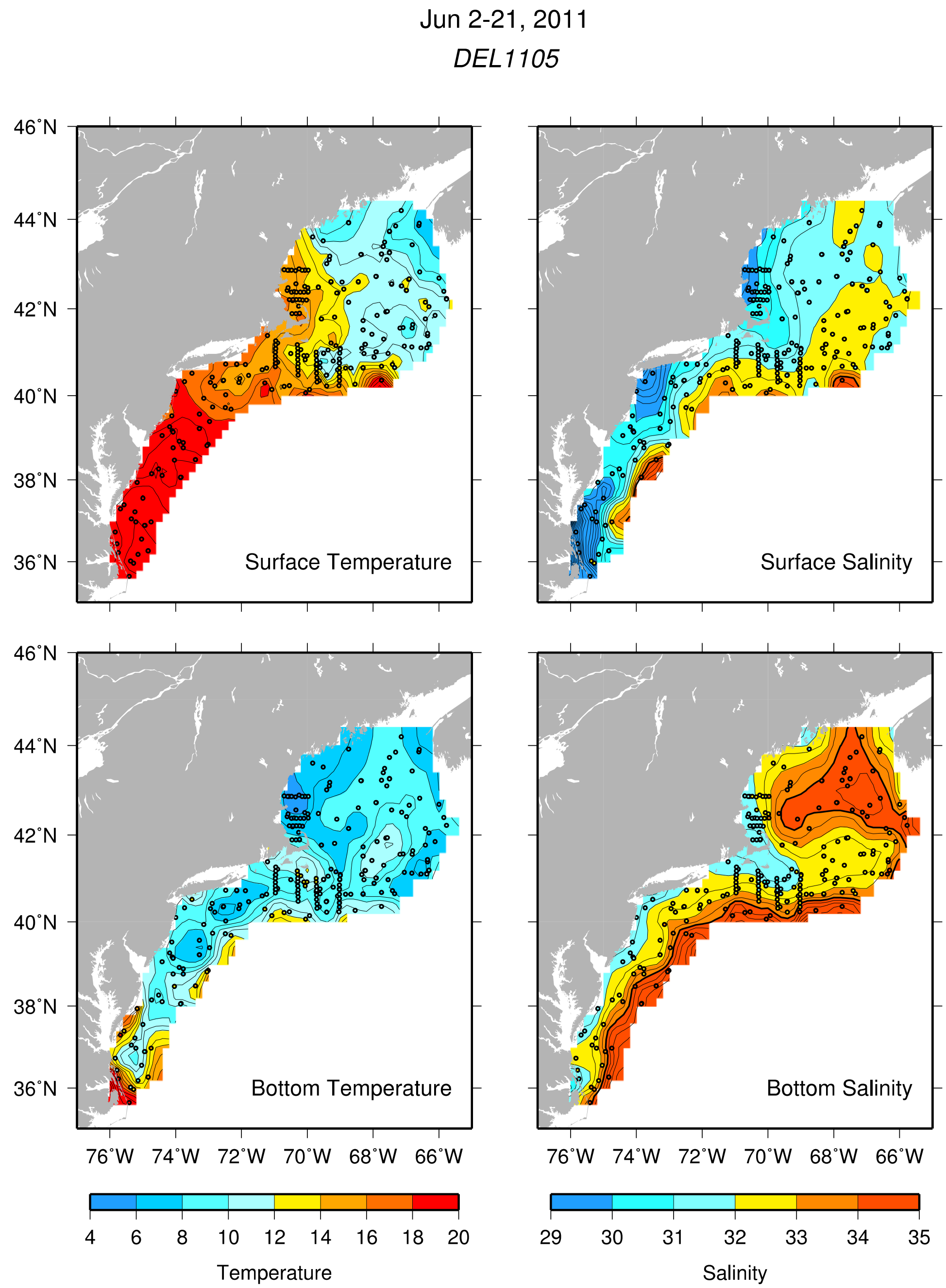

Figure 8c. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during the June EcoMon survey (June 2-21, 2011). Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

Jun 2-21, 2011

DEL1105

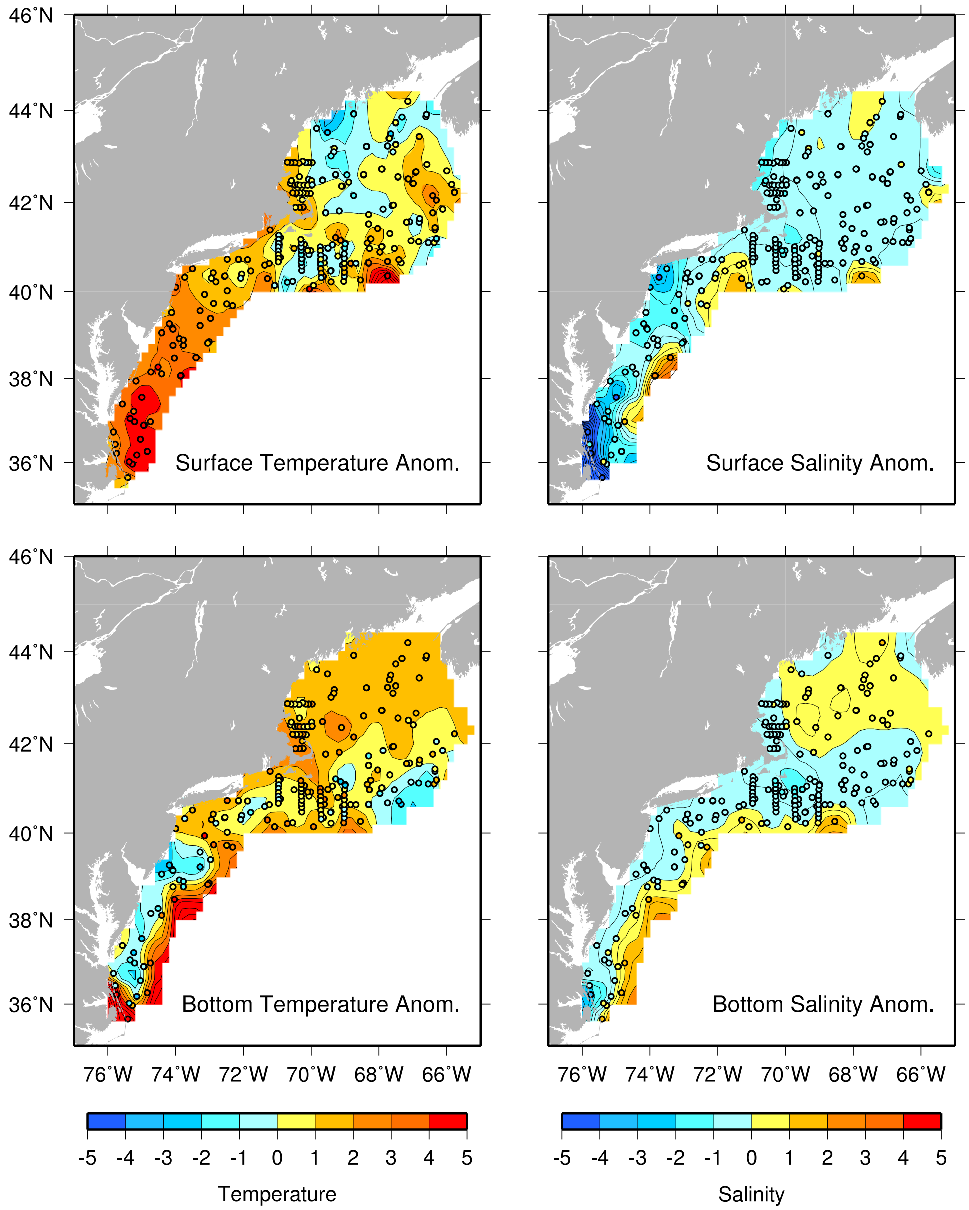

Figure 8d. Near-surface (top) and near-bottom (bottom) temperature anomaly (left) and salinity anomaly (right) distributions during the June EcoMon survey (June 2-21, 2011). Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

Jul/Aug, 2011

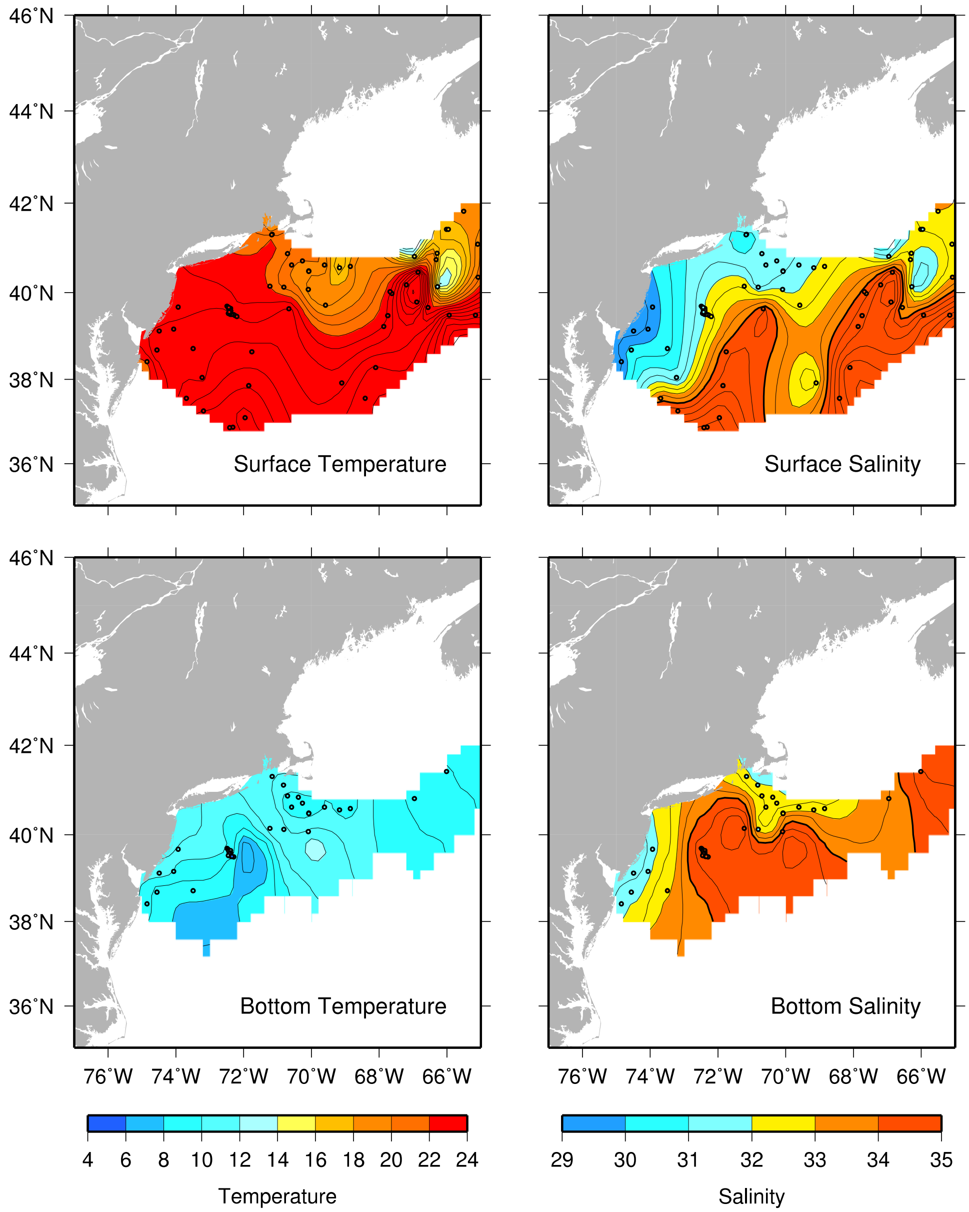

Figure 9a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during January-February 2011. Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

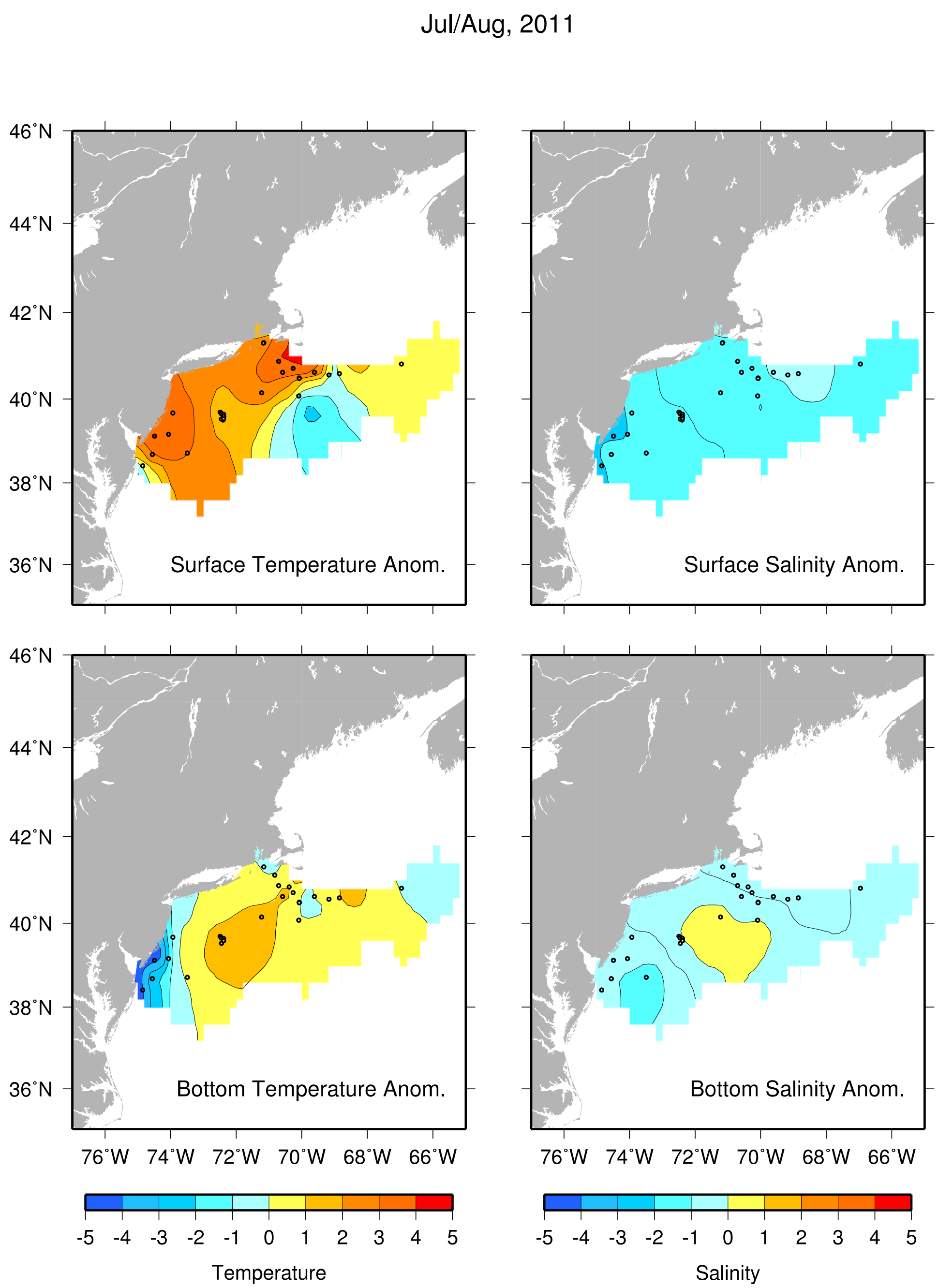

Figure 9b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during July-August, 2011. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

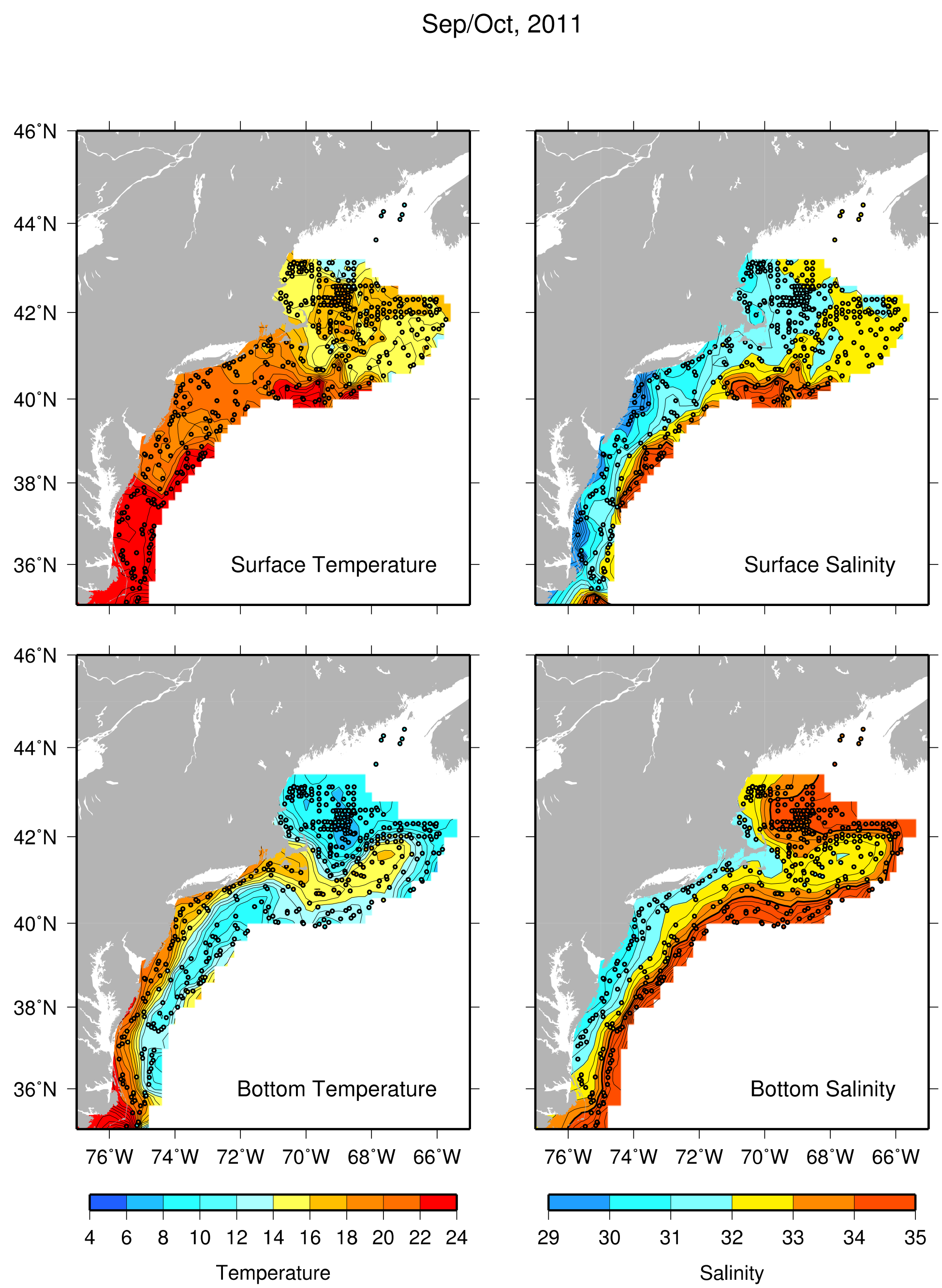

Figure 10a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during September-October 2011. Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

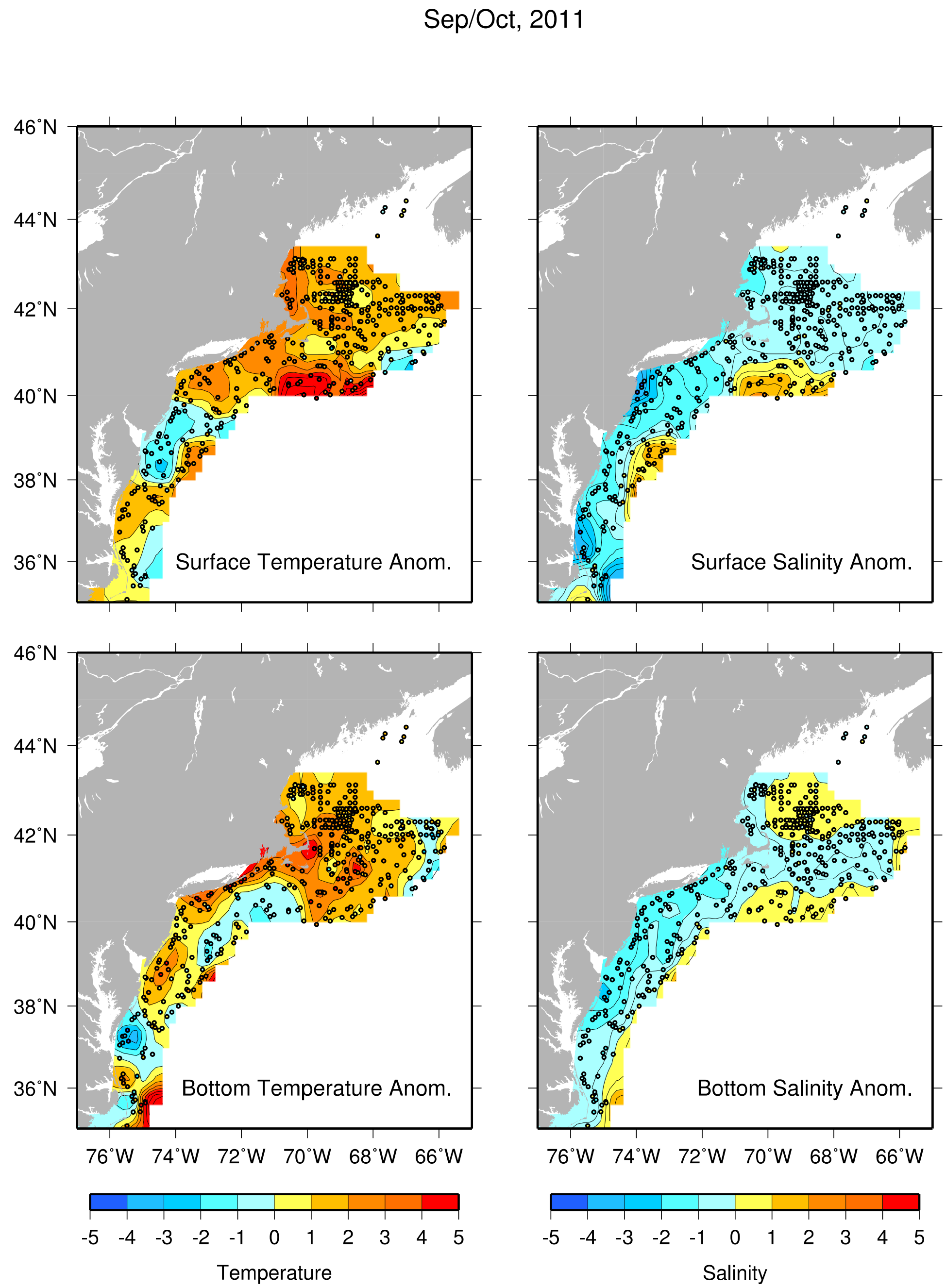

Figure 10b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during September-October 2011. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

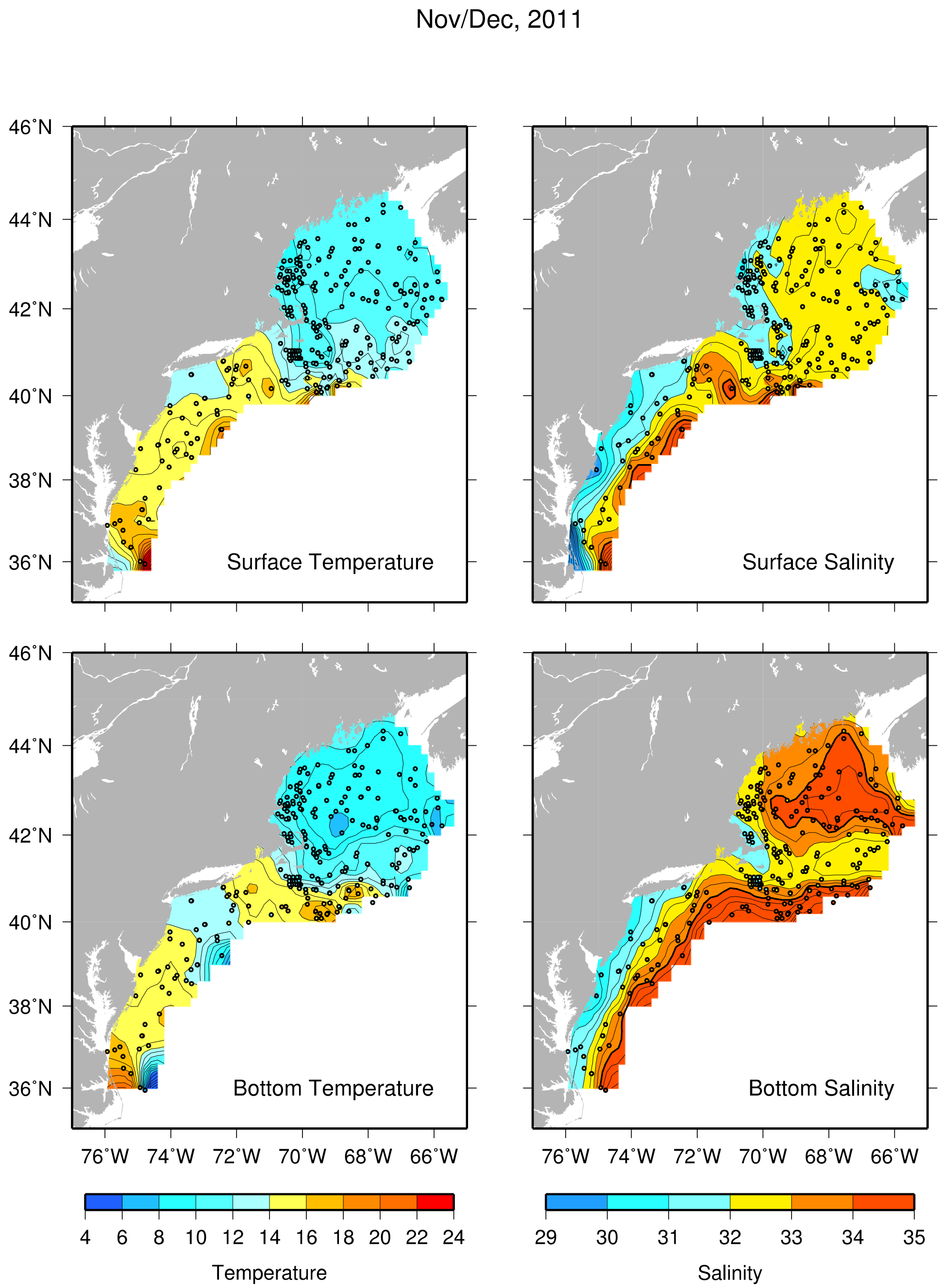

Figure 11a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during for November-December 2011. Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

Nov/Dec, 2011

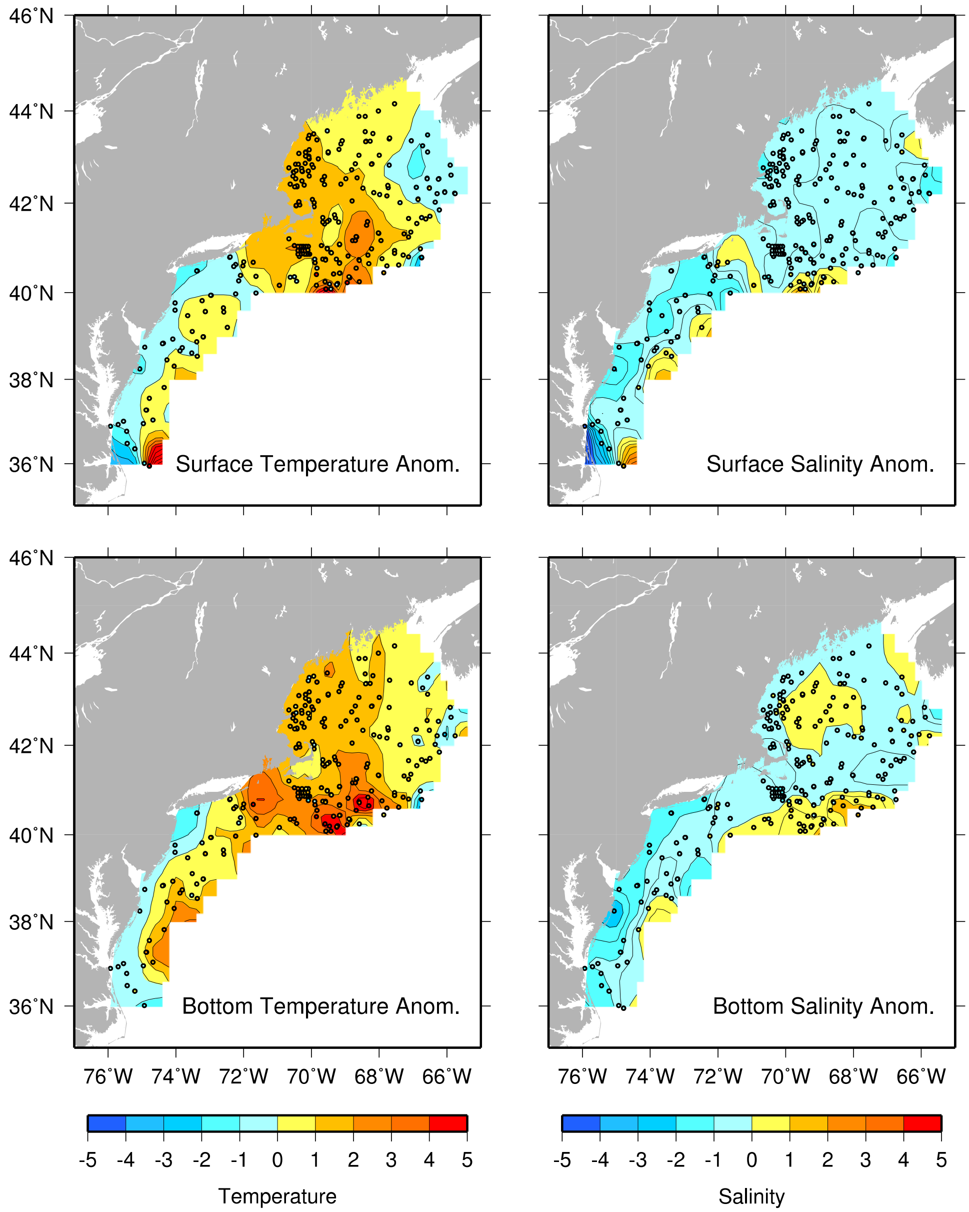

Figure 11b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during November-December 2011. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

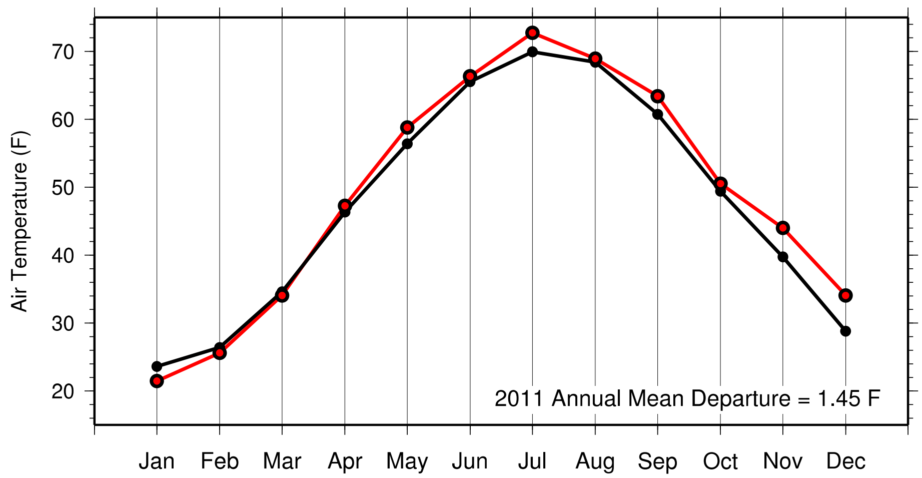

Figure 12. Monthly mean air temperature over the Northeastern U.S. for the years 1971-2000 (black) and 2011 (red), plotted from climate summary data compiled by the Northeast Regional Climate Center (http://www.nrcc.cornell.edu). The northeast region encompasses coastal states from Maine to Maryland and inland states west to West Virginia.

APPENDIX

Table A1. 2011 regional average temperature and salinity values for individual cruises that sampled within the eastern Gulf of Maine (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Gulf of Maine East

			Surface						Bottom				
Cruise	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
DEL1102	45	23	4.50	-0.26	0.21	1.69	1	14	8.33	1.00	0.26	2.66	1
HB1102	116	29	5.90	0.43	0.18	1.43	1	27	8.05	1.06	0.19	1.96	1
DEL1105	164	24	10.24	0.68	0.19	1.14	0	19	8.45	0.92	0.25	0.76	0
S11101	165	3	10.95	1.33	0.55	-9.99	1	3	6.69	-1.82	0.52	-9.99	1
DEL1108	266	23	16.93	1.64	0.22	2.92	1	22	8.70	0.53	0.20	3.00	1
HB1105	303	21	11.40	-0.06	0.22	1.38	0	20	9.20	0.42	0.23	1.33	0
DEL1109	319	16	10.76	0.21	0.26	2.47	1	10	8.15	0.05	0.31	5.10	1

			Surface						Bottom				
Cruise	CD	#obs	Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Salinity	Anomaly	SDV1	SDV2	Flag
DEL1102	45	23	4.50	-0.26	0.21	1.69	1	14	8.33	1.00	0.26	2.66	1
HB1102	116	29	5.90	0.43	0.18	1.43	1	27	8.05	1.06	0.19	1.96	1
DEL1105	164	24	10.24	0.68	0.19	1.14	0	19	8.45	0.92	0.25	0.76	0
S11101	165	3	10.95	1.33	0.55	-9.99	1	3	6.69	-1.82	0.52	-9.99	1
DEL1108	266	23	16.93	1.64	0.22	2.92	1	22	8.70	0.53	0.20	3.00	1
HB1105	303	21	11.40	-0.06	0.22	1.38	0	20	9.20	0.42	0.23	1.33	0
DEL1109	319	16	10.76	0.21	0.26	2.47	1	10	8.15	0.05	0.31	5.10	1

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A2. 2011 regional average temperature and salinity values for individual cruises that sampled within the western Gulf of Maine (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Gulf of Maine West

			Surface						Bottom				
Cruise	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
DEL1102	45	52	5.00	0.04	0.20	0.77	0	41	7.48	1.75	0.19	1.08	0
HB1102	121	53	7.04	0.74	0.15	0.73	0	52	7.17	2.04	0.13	0.96	0
DEL1105	166	43	12.03	0.16	0.17	1.17	0	36	7.52	1.70	0.17	0.96	0
S11101	167	7	11.83	-0.57	0.43	3.28	1	7	6.21	0.56	0.37	2.58	1
DEL1108	268	146	16.70	1.44	0.09	1.07	1	146	7.97	1.70	0.08	1.10	1
HB1105	310	53	11.76	0.98	0.16	0.93	0	53	8.68	1.33	0.13	0.99	0
DEL1109	321	19	10.72	1.11	0.24	1.87	1	17	8.36	1.28	0.23	3.29	1
DEL1110	339	16	10.13	1.77	0.28	2.63	1	14	9.55	1.59	0.28	2.32	1

			Surface						Bottom				
Cruise	CD	#obs	Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Salinity	Anomaly	SDV1	SDV2	Flag
DEL1102	45	52	32.33	-0.66	0.13	0.42	0	41	33.55	0.00	0.11	0.43	0
HB1102	121	53	31.49	-0.94	0.10	0.91	0	52	33.42	0.09	0.07	0.51	0
DEL1105	166	43	31.41	-0.64	0.11	0.35	0	36	33.24	-0.05	0.10	0.54	0
S11101	167	7	31.36	-0.70	0.27	0.98	1	7	32.19	-0.63	0.22	0.91	1
DEL1108	268	146	31.70	-0.46	0.06	0.30	1	146	33.80	0.14	0.04	0.30	1
HB1105	310	53	32.16	-0.51	0.10	0.26	0	53	33.61	-0.01	0.08	0.38	0
DEL1109	321	19	32.20	-0.60	0.16	0.83	1	17	33.86	0.07	0.13	1.07	1
DEL1110	339	16	32.03	-0.67	0.19	1.33	1	14	32.86	-0.17	0.16	1.05	1

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A3. 2011 regional average temperature and salinity values for individual cruises that sampled within the Georges Bank area (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Georges Bank

			Surface						Bottom				
Cruise	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
DEL1102	42	37	5.97	0.79	0.18	0.68	0	29	6.10	0.13	0.22	1.11	0
HB1102	99	55	5.57	0.37	0.14	1.03	0	42	6.03	0.77	0.17	0.92	0
S11101	163	26	10.98	0.65	0.23	1.22	0	24	8.01	0.19	0.25	1.05	0
DEL1105	163	57	11.61	1.07	0.15	1.33	0	53	8.64	0.34	0.16	0.90	0
HB1103	174	11	15.60	0.26	0.39	3.04	1	4	9.14	0.82	0.64	6.81	1
DEL1108	267	19	16.47	1.25	0.22	1.10	1	18	13.87	1.15	0.23	2.58	1
HB1105	289	58	16.10	1.37	0.15	1.90	0	44	13.61	1.14	0.17	1.64	0
DEL1109	318	28	12.91	0.70	0.22	1.22	0	23	13.81	2.32	0.25	2.24	0
DEL1110	337	31	12.21	1.49	0.20	1.79	1	29	12.76	2.11	0.22	1.47	1

			Surface						Bottom				
Cruise	CD	#obs	Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Salinity	Anomaly	SDV1	SDV2	Flag
DEL1102	42	37	33.01	0.06	0.11	0.41	0	29	33.08	-0.10	0.13	0.35	0
HB1102	99	55	32.48	-0.52	0.08	0.39	0	42	32.84	-0.33	0.10	0.49	0
S11101	163	26	32.06	-0.68	0.14	0.36	0	24	32.51	-0.64	0.15	0.37	0
DEL1105	163	57	32.18	-0.67	0.09	0.36	0	53	32.52	-0.50	0.10	0.39	0
HB1103	174	11	32.65	-0.78	0.24	1.70	1	4	33.05	-0.35	0.40	2.52	1
DEL1108	267	19	32.08	-0.48	0.13	0.18	1	18	32.38	-0.28	0.13	0.30	1
HB1105	289	58	32.45	-0.30	0.09	0.67	0	44	32.64	-0.33	0.10	0.52	0
DEL1109	318	28	32.44	-0.38	0.13	0.54	0	23	33.43	0.25	0.15	0.71	0
DEL1110	337	31	32.26	-0.55	0.11	0.87	1	29	32.84	-0.32	0.13	0.68	1

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A4. 2011 regional average temperature and salinity values for individual cruises that sampled within the northern Middle Atlantic Bight (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Northern Mid Atlantic Bight

Cruise	CD	#obs	Surface Temp	Anomaly	SDV1	SDV2	Flag	#obs	Bottom Temp	Anomaly	SDV1	SDV2	Flag
DEL1101	15	2	10.11	-0.80	1.03		1						
DEL1102	36	22	5.57	-0.49	0.28	0.99	0	17	5.80	-0.74	0.32	1.40	0
HB1102	82	55	5.27	0.60	0.17	0.81	0	47	5.13	-0.35	0.20	1.73	0
S11101	141	14	12.04	1.14	0.33	3.11	1	14	6.92	0.57	0.33	2.76	1
DEL1105	161	63	15.59	1.92	0.20	1.32	0	56	8.74	1.08	0.22	1.40	0
HB1103	186	16	18.89	2.57	0.35	2.06	1	13	10.29	0.52	0.36	3.28	1
HB1104	221	1	24.82	3.11	1.77		1						
HB1105	273	49	20.40	2.54	0.18	1.74	0	42	13.48	1.02	0.22	2.16	0
DEL1109	311	24	14.21	0.13	0.27	1.00	0	23	14.95	1.67	0.28	1.83	0
DEL1110	340	30	12.13	2.28	0.23	1.54	1	25	11.77	1.65	0.24	1.03	1

Cruise	CD	#obs	Surface Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Bottom Salinity	Anomaly	SDV1	SDV2	Flag
DEL1101	15	2	34.08	-0.33	0.69		1						
DEL1102	36	22	32.78	-0.41	0.18	0.48	0	17	32.90	-0.67	0.19	0.41	0
HB1102	82	55	32.35	-0.54	0.11	0.60	0	47	32.64	-0.81	0.12	0.46	0
S11101	141	14	31.80	-0.29	0.22	1.70	1	14	32.28	-0.74	0.20	0.70	1
DEL1105	161	63	31.69	-0.67	0.13	0.70	0	56	32.48	-0.61	0.13	0.49	0
HB1103	186	16	32.22	-0.75	0.21	1.22	1	13	33.21	-0.53	0.20	1.15	1
HB1104	221	1	31.81	-2.00	1.02		1						
HB1105	273	49	32.09	-0.58	0.12	1.36	0	42	32.90	-0.53	0.13	0.67	0
DEL1109	311	24	32.39	-0.62	0.17	0.82	0	23	33.38	-0.34	0.16	0.71	0
DEL1110	340	30	32.23	-0.43	0.14	0.79	1	25	32.14	-0.62	0.14	0.67	1

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A5. 2011 regional average temperature and salinity values for individual cruises that sampled within the southern Middle Atlantic Bight (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Southern Mid Atlantic Bight

			Surface						Bottom				
Cruise	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
DEL1101	15	31	9.15	-0.94	0.25	0.85	1	14	7.47	-1.04	0.35	1.94	1
DEL1102	35	34	5.94	-0.65	0.24	1.42	0	24	5.41	-0.31	0.28	1.16	1
HB1102	70	69	6.79	0.59	0.16	1.37	0	58	6.49	0.35	0.21	1.58	0
S11101	135	35	12.94	0.94	0.22	1.86	1	35	6.68	-0.95	0.24	1.35	1
DEL1105	156	42	20.65	3.52	0.20	0.95	0	39	10.23	0.54	0.23	2.69	0
HB1103	174	14	22.12	2.56	0.36	1.05	1	11	10.28	1.23	0.46	3.09	1
HB1104	220	29	23.95	1.46	0.29	0.90	1	1	9.86	3.03	1.32	-9.99	1
HB1105	261	90	22.08	0.40	0.14	1.56	0	73	14.02	-0.02	0.18	2.29	0
DEL1109	311	39	15.70	0.17	0.22	1.47	0	37	15.09	0.49	0.25	1.11	0
			Surface						Bottom				
Cruise	CD	#obs	Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Salinity	Anomaly	SDV1	SDV2	Flag
DEL1101	15	31	33.61	-0.80	0.18	2.00	1	14	33.57	-0.08	0.22	0.43	1
DEL1102	35	34	32.90	-0.49	0.18	0.65	0	24	32.79	-0.39	0.17	0.54	1
HB1102	70	69	32.80	-0.46	0.12	1.04	0	58	33.12	-0.48	0.12	0.48	0
S11101	135	35	32.21	-0.45	0.16	0.95	1	35	32.81	-0.78	0.14	0.40	1
DEL1105	156	42	30.50	-1.56	0.16	1.77	0	39	32.94	-0.31	0.14	0.71	0
HB1103	174	14	31.65	-1.03	0.26	1.02	1	11	33.03	-0.23	0.26	0.95	1
HB1104	220	29	31.96	-1.51	0.19	0.67	1	1	33.51	0.17	0.81	-9.99	1
HB1105	261	90	31.30	-1.01	0.11	1.48	0	73	32.10	-1.04	0.11	0.65	0
DEL1109	311	39	32.32	-0.65	0.17	1.22	0	37	32.57	-0.82	0.15	0.61	0

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A6. 2011 Temperature, salinity and volume of the shelf water in the Middle Atlantic Bight during 2011. The shelf water is defined as water within the upper 100 meters having salinity less than 34.

CD	Temp	Temp. Anomaly	Salt	Salt Anomaly	SHW Temp	SHW T. Anom	SHW Salt	SHW S. Anom	SHW Volume	SHW Vol. Anomaly
MABN										
36	6.76	0.16	33.18	-0.36	5.76	0.34	32.84	-0.29	2327.84	336.85
82	5.70	0.19	32.83	-0.51	5.30	0.87	32.66	-0.39	2339.72	257.80
163	10.75	0.43	32.53	-0.70	10.49	0.78	32.34	-0.48	2227.30	300.71
273	16.65	1.71	33.24	-0.39	16.10	1.59	32.50	-0.40	1734.97	192.54
311	15.13	0.79	33.34	-0.38	14.49	0.73	32.75	-0.26	1809.13	451.64
MABS										
16	9.99	0.05	34.27	0.05	6.95	-0.28	33.30	0.17	1735.12	563.37
35	7.70	-1.19	33.61	-0.57	5.39	-0.32	32.82	-0.42	1957.07	789.36
70	7.89	-0.04	33.64	-0.34	6.54	1.39	33.09	-0.29	2496.55	1177.90
135	9.19	-0.78	32.84	-0.60	8.42	-1.02	32.62	-0.24	3580.41	1655.11
157	13.55	2.07	32.99	-0.31	12.54	1.51	32.07	-0.54	2166.33	43.48
261	16.84	0.42	32.96	-0.54	16.07	-0.21	32.21	-0.72	2540.20	413.86
312	15.54	0.84	33.09	-0.85	15.13	0.18	32.69	-0.36	2548.01	910.72

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